Abundance and recruitment indices of lobster (*Homarus americanus*) in the Gaspé (Quebec), from 2007 to 2011

Benoît Bruneau and Louise Gendron

Science Branch
Fisheries and Oceans Canada
Maurice Lamontagne Institute
P.O. Box 1000, 850 route de la Mer
Mont-Joli, Québec G5H 3Z4

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G5H 3Z4

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TABLE OF CONTENTS

TABLE OF CONTENTS iii
LIST OF TABLES iv
LIST OF FIGURES v
LIST OF APPENDICES vii
ABSTRACT ix
RÉSUMÉ x
1.0 INTRODUCTION 1
2.0 MATERIAL AND METHODS 4
2.1 SAMPLING 4
2.2 INFORMATION COLLECTED 8
2.3 DATA ANALYSIS 11
2.3.1 Spatio-temporal variations in abundance 11
2.3.2 Spatio-temporal structure 15
2.3.3 Forecasting tool of the recruitment to the fishery 15
3.0 RESULTS 16
3.1 OVERVIEW 16
3.2 SPATIO-TEMPORAL VARIATIONS IN ABUNDANCE (CPUE) 20
3.2.1 Analyses of Variance 20
3.2.2 Overall trends 29
3.3 SPATIO-TEMPORAL STRUCTURE 30
3.4 FORECASTING TOOL OF THE RECRUITMENT TO THE FISHERY 31
3.4.1. Forecasts – sub-areas 31
3.4.2. Forecasts – Areas 20A and 20B 37
4.0 DISCUSSION 39
4.1 ABUNDANCE INDEX CALCULATION (CPUE) 39
4.2 SPATIO-TEMPORAL VARIATIONS IN ABUNDANCE (CPUE) 42
4.3 RECRUITMENT INDICATOR 44
5.0 CONCLUSION 47
6.0 ACKNOWLEDGEMENTS 47
7.0 REFERENCES 49
8.0 APPENDICES 52

LIST OF TABLES

Table 1. Number of fishers by sub-area and year involved in collecting data.....4

Table 2. Carapace length (mm) and categories of lobster based on the gauge's various size classes 1 to 12 (2007 to 2008) and 1 to 14 (2009 to 2011).....8

Table 3. Percentage of fishers (number in parentheses) who provided the information requested in the form for each year: fishers who provided the daily commercial catch weight for at least 85% of fishing days in the season, fishers who did not record any data on their daily catch and fishers who did not provide any position data (latitude and longitude).....9

Table 4. Total number of experimental traps hauled (regular + modified) for each fishery sub-area from 2007 to 2011. The number of regular and modified traps hauled was the same.....10

Table 5. Overall annual CPUEs for lobster (total number of lobsters/total number of traps) for pre-recruits 2 (size classes 1 to 3) and 1 (size class 4), commercial-size lobsters (size classes 5 to 13 excluding berried females) and berried females. Mean values are estimated by trap type (regular and modified). Column M/R is the ratio between the CPUE for modified traps and the CPUE for regular traps.....19

Table 6. Results of analyses verifying the ANOVA conditions for each category of lobster. "Trans" are the mathematical transformations applied to the data, where "y" is the dependent variable. B-F is the "p" value from the Brown-Forsythe test. Values of "p" to test asymmetry, kurtosis and the D'Agostino-Pearson omnibus test are also presented.....20

Table 7. Results of the 3-factor ANOVA analysis (Area, Year and Period) performed on the CPUEs of the different categories of lobster (COM, PRE1, PRE2 and BF).....21

Table 8. Results of linear regressions calculated between the mean CPUEs of the different categories of lobster for the entire LFA 20 and the year.....30

Table 9. Correlation coefficients (r) between the abundance of lobster in the various sub-areas between two consecutive years, for each category of lobster. The "p" value is shown for each correlation coefficient (r).....31

Table 10. Results of linear regressions calculated between the different categories (classes) of lobster for time intervals of 1 or 2 years. The results are based on estimated mean annual CPUEs by sub-area.....33

Table 11. Results of linear regressions calculated between the different categories of lobster for time intervals of 1 or 2 years. The results are based on estimated mean annual CPUEs by area.....37

LIST OF FIGURES

Figure 1. Location of lobster fishing sub-areas in the Gaspé, Area 20A (sub-areas A1 to A10), Area 20B (sub-areas B1 to B8), Area 21 (sub-areas A and B) and 19C (Northern Gaspé). Note that sub-area 20B6 and adjacent sub-areas 20B5 and 20B7 overlap....3

Figure 2. Copy of the logbook form completed on a daily basis by the fishers participating in the project....6

Figure 3. Photograph of the gauge used by fishers to measure lobsters (carapace size) according to 12 (2007 to 2008) or 14 (2009 and 2011) size classes....7

Figure 4. Evolution of participation in the sampling campaign with experimental traps from 2007 to 2011: total number of fishers (Fishers) each year, number of fishers who participated over the last five years (Common fishers) and number of sub-areas sampled by year (Sub-areas)....11

Figure 5. Overall annual CPUEs for males and non-berried females (n-b) (total number of lobsters caught/total number of traps) by size class based on the type of trap for 2007 to 2011. The dotted gray line separates pre-recruit lobsters from commercial-size lobsters. For each year and each category, the number of lobsters, the total number of traps hauled and the percentage of males and n-b females observed in the total catch of the year are shown....17

Figure 6. Overall annual CPUEs for berried females (total number of lobsters caught/total number of traps) by size class based on the type of trap for 2007 to 2011. The dotted gray line separates pre-recruit lobsters from commercial-size lobsters. For each year and each category, the number of lobsters, the total number of traps hauled and the percentage of berried females observed in the total catch of the year are shown....18

Figure 7. Mean CPUEs in number/trap (+ standard error) of estimated COM per sub-area for 2007 to 2011. The horizontal lines are, respectively from top to bottom, 75th, 50th (median) and 25th percentiles....23

Figure 8. Mean CPUEs in number/trap (+ standard error) of estimated PRE1 per sub-area for 2007 to 2011. The horizontal lines are, respectively from top to bottom, 75th, 50th (median) and 25th percentiles....25

Figure 9. Mean CPUEs in number/trap (+ standard error) of estimated PRE2 per sub-area for 2007 to 2011. The horizontal lines are, respectively from top to bottom, 75th, 50th (median) and 25th percentiles....27

Figure 10. Mean CPUEs in number/trap (+ standard error) of estimated BF per sub-area for 2007 to 2011. The horizontal lines are, respectively from top to bottom, 75th, 50th (median) and 25th percentiles....29

Figure 11. Mean CPUEs in number/trap (± confidence interval) estimated for the four categories of lobster (COM, PRE1, PRE2, BF) from 2007 to 2011....30

Figure 12. Relationships between $PRE1_t$ (size 4) and COM_{t+1} (sizes 5-6). The dots are annual means by sub-area. The numbers under each dot represent the year time "t". Areas 20A and 20B are respectively shown in (A) and (B). The lines represent the regression lines described in Table 10 (dotted: $p \geq 0.05$; full: $p < 0.05$). Extreme values are identified by "*" and were not considered in the analysis. 34

Figure 13. Relationships between $PRE2_t$ (size 3) and $PRE1_{t+1}$ (size 4). The dots are annual means by sub-area. The numbers under each dot represent the year time "t". Areas 20A and 20B are respectively shown in (A) and (B). The lines represent the regression lines described in Table 10 (dotted: $p \geq 0.05$; full: $p < 0.05$). Extreme values are identified by "*" and were not considered in the analysis. 35

Figure 14. Relationships between $PRE2_t$ (size 3) and COM_{t+2} (sizes 5-6). The dots are annual means by sub-area. The numbers under each dot represent the year time "t". Areas 20A and 20B are respectively shown in (A) and (B). The lines represent the regression lines described in Table 10 (dotted: $p \geq 0.05$; full: $p < 0.05$). Extreme values are identified by "*" and were not considered in the analysis. 36

Figure 15. Relationships between $PRE1_t$ (size 4) and COM_{t+1} (sizes 5-6) for each area (20A and 20B). The dots are annual means by area. The numbers under each dot represent the year time "t". The lines represent the regression lines described in Table 11 (dotted: $p \geq 0.05$; full: $p < 0.05$). 37

Figure 16. Relationships between $PRE2_t$ (size 3) and $PRE1_{t+1}$ (size 4) for each area (20A and 20B). The dots are annual means by area. The numbers under each dot represent the year time "t". The lines represent the regression lines described in Table 11 (dotted: $p \geq 0.05$; full: $p < 0.05$)....38

Figure 17. Relationships between $PRE2_t$ (size 3) and COM_{t+2} (sizes 5-6) for each area (20A and 20B). The dots are annual means by area. The numbers under each dot represent the year time "t". The lines represent the regression lines described in Table 11 (dotted: $p \geq 0.05$; full: $p < 0.05$). 38

LIST OF APPENDICES

Appendix 1. Variation of weekly CPUEs of COM for each year. The data were normalized (centered and reduced) by sub-area and year. 52

Appendix 2. Variation of weekly CPUEs of PRE1 for each year. The data were normalized (centered and reduced) by sub-area and year. 53

Appendix 3. Variation of weekly CPUEs of PRE2 for each year. The data were normalized (centered and reduced) by sub-area and year. 54

Appendix 4. Variation of weekly CPUEs of BF for each year. The data were normalized (centered and reduced) by sub-area and year. 55

Appendix 5. Mean annual CPUEs in number/trap (± standard error) for COM, PRE1, PRE2 and BF categories, estimated by sub-area for 2007 to 2011. 56

Appendix 6. Results ("p" values) of the analysis of multiple comparisons between years by sub-area for COM. 58

Appendix 7. Results ("p" values) of the analysis of multiple comparisons between sub-areas by year for COM. 59

Appendix 8. Results ("p" values) of the analysis of multiple comparisons between years by sub-area for PRE1. 62

Appendix 9. Results ("p" values) of the analysis of multiple comparisons between sub-areas by year for PRE1. 63

Appendix 10. Results ("p" values) of the analysis of multiple comparisons between years by sub-area for PRE2. 66

Appendix 11. Results ("p" values) of the analysis of multiple comparisons between sub-areas by year for PRE2. 67

Appendix 12. Results ("p" values) of the analysis of multiple comparisons between years by sub-area for BF. 70

Appendix 13. Results ("p" values) of the analysis of multiple comparisons between sub-areas by year for BF. 71

Appendix 14. Relationship between the abundance of COM from various sub-areas for two consecutive years. Abundance corresponds to the mean annual CPUE (natural logarithm), which were used in the correlation analyses. The empty circles represent extreme values that were excluded from the analyses. 74

Appendix 15. Relationship between the abundance of PRE1 from various sub-areas for two consecutive years. Abundance corresponds to the mean annual CPUE (natural logarithm), which were used in the correlation analyses. The empty circles represent extreme values that were excluded from the analyses. 75

Appendix 16. Relationship between the abundance of PRE2 from various sub-areas for two consecutive years. Abundance corresponds to the mean annual CPUE (natural logarithm), which were used in the correlation analyses. The empty circles represent extreme values that were excluded from the analyses. 76

Appendix 17. Relationship between the abundance of BF from various sub-areas for two consecutive years. Abundance corresponds to the mean annual CPUE (natural logarithm), which were used in the correlation analyses. The empty circles represent extreme values that were excluded from the analyses. 77

Appendix 18. Relationship between the abundance of the different categories of lobster (A: COM-PRE1, B: PRE1-PRE2 and C: COM-PRE2). Each graph includes the five years (2007 to 2011). Abundance corresponds to the mean annual CPUE for each sub-area of Areas 20A and 20B. 78

Appendix 19. Relationships between the abundance of PRE1 (size 4) and COM (sizes 5-6) for consecutive years (t = 2007-2010 and t+1 = 2008-2011). The abundance corresponds to the mean annual CPUE for each sub-area. Trends for each sub-area (A and C) and trends for each year (B and D) are presented for each area (20A: A and B, 20B: C and D) and were estimated by the standard major axis. Extreme values are identified by "*" and were not considered in the trends. 79

Appendix 20. Relationships between PRE2 (size 3) and PRE (size 4) for consecutive years (t = 2007-2010 and t+1 = 2008-2011). The abundance corresponds to the mean annual CPUE for each sub-area. Trends for each sub-area (A and C) and trends for each year (B and D) are presented for each area (20A: A and B, 20B: C and D) and were estimated by the standard major axis. Extreme values are identified by "*" and were not considered in the trends....81

Appendix 21. Relationships between PRE2 (size 3) and COM (sizes 5-6) sparated by a 2-y interval(t = 2007-2009 and t+2 = 2009-2011). The abundance corresponds to the mean annual CPUE for each sub-area. Trends for each sub-area (A and C) and trends for each year (B and D) are presented for each area (20A: A and B, 20B: C and D) and were estimated by the standard major axis. Extreme values are identified by "*" and were not considered in the trends....83

ABSTRACT

Bruneau, B. and L. Gendron. 2012. Abundance and recruitment indices of lobster (*Homarus americanus*) in the Gaspé (Quebec), from 2007 to 2011. Can. Tech. Rep. Fish. Aquat. Sci. 3015 : x + 84p.

From 2007 to 2011, between 22 and 27 lobster fishers from the Gaspé (Quebec) collected data on lobster on a daily basis throughout the fishing season. The objectives of the study were to describe the spatio-temporal abundance of different categories of lobster (commercial, COM, two groups of pre-recruits, PRE1 and PRE2, and berried females, FO) along the Gaspé Peninsula and to develop a recruitment index to provide short-term forecasts (1-2 years) of the abundance of commercial lobsters that will constitute the landings. Data were obtained from two regular lobster traps and two modified traps (without escapement vents to retain small lobsters), arranged alternately on a fishing line and hauled each day. All lobster caught were sexed and measured with a calibrated gauge. During the study, between 4072 and 5776 experimental traps were hauled and between 11,917 and 18,428 lobsters were captured and measured annually. Variability in the abundance of lobster, expressed in catch per unit of effort (CPUE) (number of lobster per trap) was studied using a three-way ANOVA followed by multiple comparisons tests to highlight the differences between the 12 sub-areas studied for a given year and between years within a sub-area, taking into account inter-annual variability. Spatial patterns of distribution were examined by comparing the CPUEs of the different sub-areas to the 25th, 50th and 75th percentiles of the distribution of all CPUE values, as well by using correlation analyses. The development of a forecasting tool was explored using regression analysis between the abundance of COM for a given year to that of PRE1 and PRE2, one and two years earlier, respectively. Data collected between 2007 and 2011 showed that during the study period, there was an increase in lobster abundance (all categories) in the majority of sub-areas. The study also revealed a spatial structure in the distribution of each category of lobster suggesting that certain areas could perhaps be more favorable for PRE and others for COM. There was a positive relationship between the abundance of PRE1 a given year and COM the following year across the entire study area. Relationships at the sub-area scale may be more difficult to establish because of the possibility of spatial segregation between the two categories of lobster. A longer time series is needed however to provide longer-term (2 years) forecast of the trend in the abundance of commercial lobster.

RÉSUMÉ

Bruneau, B. and L. Gendron. 2012. Abundance and recruitment indices of lobster (*Homarus americanus*) in the Gaspé (Quebec), from 2007 to 2011. Can. Tech. Rep. Fish. Aquat. Sci. 3015 : x + 84p.

Entre 2007 et 2011, de 22 à 27 pêcheurs de homard de la Gaspésie (Québec) ont participé à la collecte de données sur le homard sur une base quotidienne durant toute la saison de pêche. L'étude visait à décrire les patrons spatio-temporels de l'abondance de différentes catégories de homard (commerciaux, COM, deux groupes de prérecrues, PRE1 et PRE2, et femelles oeuvées, FO) sur le territoire gaspésien et à développer un indice du recrutement à la pêche permettant de prévoir à court terme (1-2 ans) l'abondance des homards commerciaux qui constitueront les débarquements. Les données ont été obtenues à partir de deux casiers réguliers et deux casiers modifiés (sans évents d'échappement pour retenir les petits homards), disposés en alternance sur une ligne de pêche et relevés quotidiennement. Tous les homards capturés étaient sexés et mesurés à l'aide d'un gabarit gradué. Au cours de l'étude, entre 4 072 et 5 776 casiers expérimentaux ont été levés et entre 11 917 et 18 428 homards ont été capturés et mesurés annuellement. La variabilité dans l'abondance du homard, exprimée en prise par unit d'effort (PUE) (nombre de homard par casier), a été étudiée à l'aide d'une ANOVA à trois facteurs, suivi de comparaisons multiples, afin de faire ressortir les différences entre les 12 sous-zones étudiées pour une même année et entre les années à l'intérieur d'une sous-zone, tout en tenant compte de la variabilité intra-annuelle. Les patrons spatiaux de distribution entre les sous-zones ont été examinés en comparant les PUE des différentes sous-zones aux 25^{e}, 50^{e} et 75^{e} centiles de la distribution de l'ensemble des valeurs de PUE, ainsi que par des analyses de corrélation. Le développement de l'outil de prévision a été fait à l'aide d'analyses de régression entre l'abondance des COM une année donnée et les PRE1 et les PRE2, une et deux années plus tôt, respectivement. Les données recueillies entre 2007 et 2011 ont montré qu'il y a eu au cours cette période, une augmentation de l'abondance du homard dans la majorité des sous-zones. L'étude a aussi révélé une structure spatiale dans la distribution de chacune des catégories de homard avec entre autres des zones qui sembleraient plus favorables pour les PRE et d'autres pour les COM. Il existe une relation positive entre l'abondance des PRE1 d'une année et les homards de taille commerciale l'année suivante à l'échelle de l'ensemble de la zone d'étude. Les relations à l'échelle des sous-zones sont parfois plus difficiles à établir en raison de la possibilité de ségrégation spatiale entre les deux catégories de homard. Une plus longue série temporelle sera cependant nécessaire pour prévoir à plus long terme (2 ans) la tendance dans l'abondance des homards commerciaux.

1.0 INTRODUCTION

The lobster fishery on the Gaspé Peninsula (Quebec), as in most fishing areas (LFAs) in the Atlantic, is considered a recruitment fishery (Gendron and Savard 2012, FRCC 1995 and 2007). Fishing pressure indicators (exploitation rates) estimated in recent years (2005 to 2010) ranged between 77 and 84% (Gendron and Savard 2012). Therefore, in a given year, the fishery depends largely on lobsters that have moulted to commercial size in the previous year. A monitoring program for commercial lobster catches has been in place in the Gaspé since 1986. This sampling program helps gather information on lobster populations and calculate stock status indicators. It mainly affects the commercial portion of the lobster population because it is conducted using commercial fishing gear that are very selective in terms of the sizes retained (Gauthier and Hazel 1986). These gear types provide only very limited information on sub-commercial-size lobsters. In addition, the sampling program is applied only on a small spatial scale and covers only a few days of the fishing season (0.14% of fishing trips).

The acquisition of data on the portion of the lobster population that is the future recruitment for the fishery (sub-legal lobster, hereinafter referred to as pre-recruits) is important and very useful for the fishing industry. This is not yet done in the Gaspé, though it is in other regions, including the Magdalen Islands by way of a trawl (Gendron and Savard 2012). In the Maritimes, pre-recruit data has been collected for several years with traps that are modified to retain small lobsters. In 1999, a pre-recruit monitoring program was implemented in the coastal regions of the southern Gulf of St. Lawrence, within the framework of a collaborative project between the industry and the Department of Fisheries and Oceans (DFO) (Gulf Region). This program focuses on pre-recruit lobster sampling, using traps with blocked escape vents (Comeau et al. 2008). The use of these traps helps retain sub-commercial-size lobsters. The project was implemented to obtain a recruitment index for forecasting short-term (1 to 2 years) landing trends. Sampling is conducted by the fishers themselves throughout the fishing season and fishers record the data in a logbook. Participation is on a voluntary basis. The participation of numerous fishers in the project has so far provided a wide spatial and temporal coverage. Similar sampling campaigns have also been conducted since 2005 in Newfoundland, since 1999 in Nova Scotia by the Fishermen and Scientist Research Society (FSRS) (Mac Donald et al. 2001, Tremblay et al. 2011, 2012), as well as in Maine (USA) (Ellis and Pelletier 2009).

Based on the project described by Comeau et al. (2008), this study was started in 2006, with the collaboration of several lobster fishers from different sub-areas of the Gaspé Peninsula (Figure 1) who were asked to fish with modified gear (blocked escape vents). This study's first objective was to obtain lobster abundance indices, not only for commercial-size lobster but also for pre-recruits and berried females, over a larger area than that covered by the DFO sampling program in order to explore spatial patterns and follow interannual fluctuations. The second objective was to develop a index of recruitment to the fishery in order to predict in the short term (1 to 2 years) the abundance of commercial-size lobsters that will make up landings. Much of the work also focused on developing a methodology for statistical analysis of the data, while taking into account their nature and limitations.

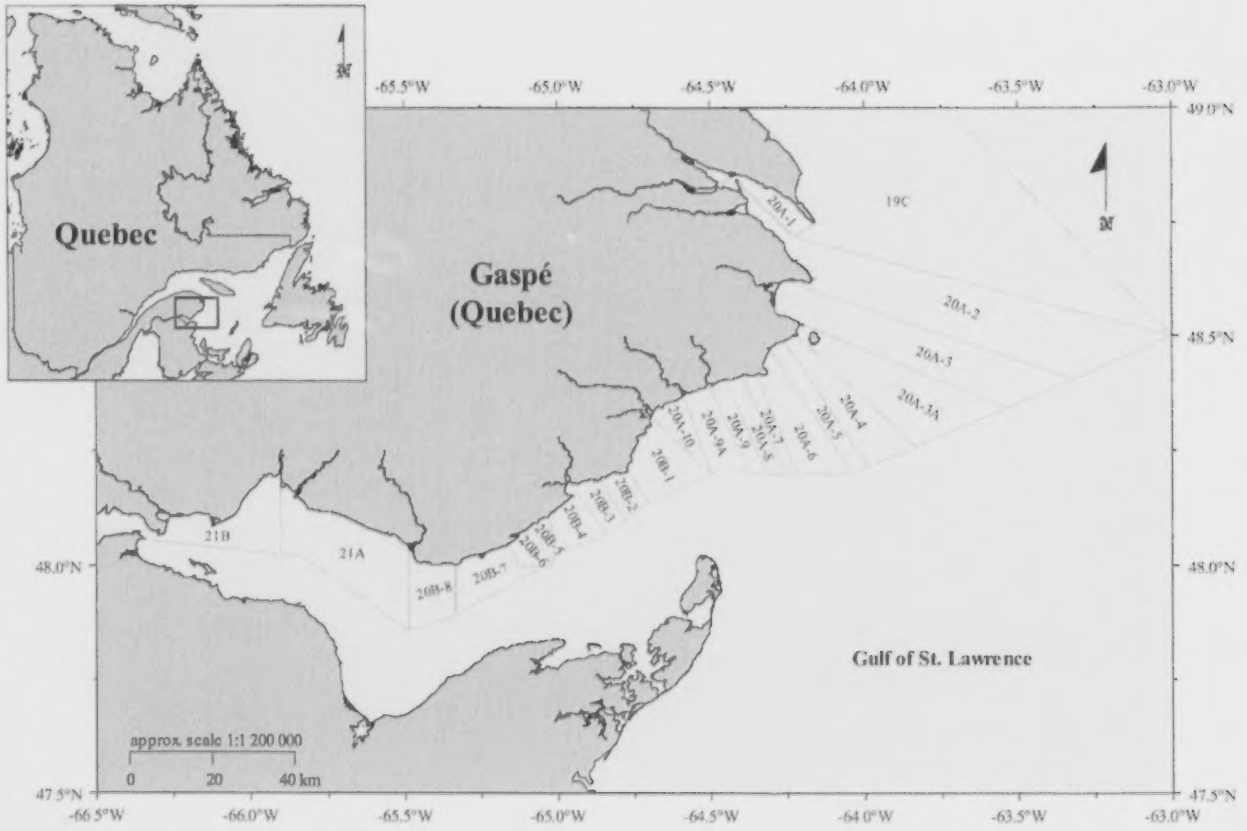


Figure 1. Location of lobster fishing sub-areas in the Gaspé, Area 20A (sub-areas A1 to A10), Area 20B (sub-areas B1 to B8), Area 21 (sub-areas A and B) and 19C (Northern Gaspé). Note that sub-area 20B6 and adjacent sub-areas 20B5 and 20B7 overlap.

2.0 MATERIAL AND METHODS

2.1 SAMPLING

Data acquisition was conducted during the fishing seasons (late April to early July) from 2006 to 2011. It should be noted that in 2006, the year the program was started, there was virtually no sampling during the first three weeks of the season because of the late delivery of logbooks. Consequently, data from the 2006 season were not used in this study and are not presented. Sampling was carried out by fishers who participated voluntarily. Fishers covered the sub-area corresponding to their fishing licence. Depending on the level of participation, each sub-area could count up to three participants (Table 1). However, though the target was a minimum of two fishers per sub-area, in many cases there was only one participant.

Table 1. Number of fishers by sub-area and year involved in collecting data.

Fishing subareas	2007	2008	2009	2010	2011
19C1	1	1	1	1	1
20A1	0	0	2	1	2
20A2	2	1	1	1	1
20A3A	1	1	1	0	0
20A4	2	2	1	1	2
20A5	2	2	2	2	2
20A6	2	2	1	1	1
20A7	1	1	1	1	1
20A8	2	2	2	2	2
20A9	3	3	2	2	3
20A9A	2	2	2	1	2
20A10	2	0	1	0	1
20B1	2	2	2	2	2
20B2	2	2	1	1	1
20B3	1	1	2	2	2
20B4	1	2	2	2	2
20B5	1	1	1	1	1
20B6	0	0	2	1	1
Total	27	25	27	22	27

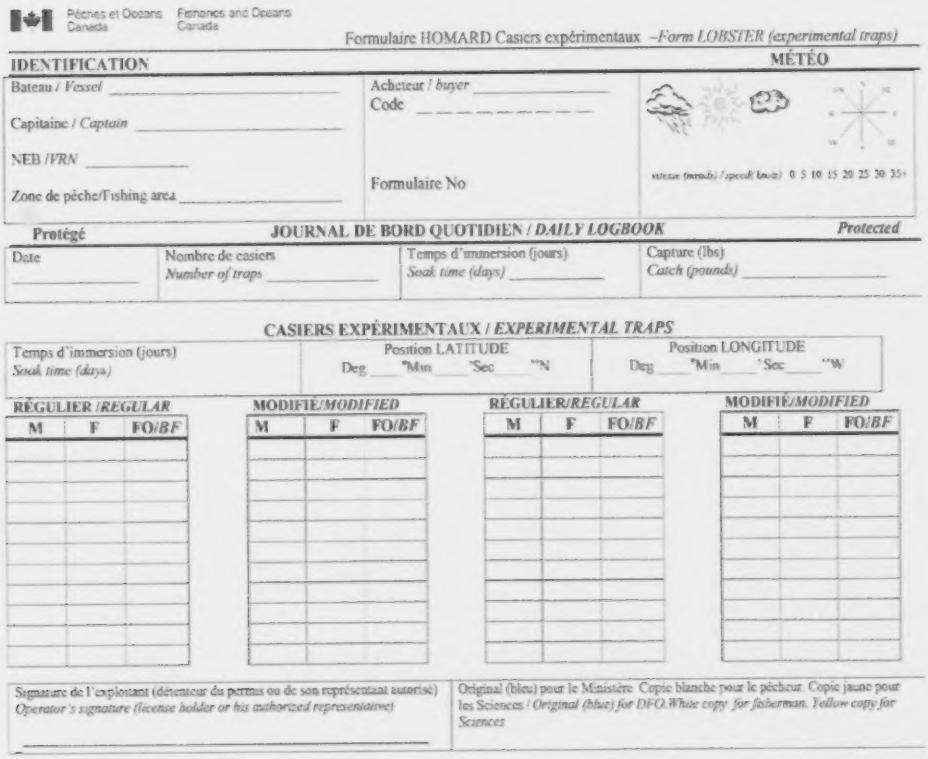
Sampling was done using four traps hereinafter referred to as experimental traps. The escape vents of two of these four traps were blocked (modified traps) to increase the retention of small lobsters. The other two were not modified (regular traps). The traps were set in alternate positions (regular and modified) at the beginning of a fishing line, which normally had six. They were hauled as often as the other traps throughout the season. As a rule, the line of experimental traps was distributed randomly among the other trap lines. Fishers used their own traps. Thus, dimensions could vary a little according to each fisher (55.3 ± 0.4 cm wide × 88.8 ± 1.1 cm long × 43.4 ± 1.6 cm high), but below the limits imposed by the regulations in force, namely, 61 cm wide × 92 cm long × 50 cm high. Each trap had only one parlour. However, they could differ from one fisher to another, in their shape (hemicylindric or rectangular) and the material used (wood or metal). Nevertheless, these differences were considered minor and for the analyses, it was assumed that the different traps were equally effective. Changes in yields have already been observed depending on the size or volume of the traps, but only when the differences in dimensions were greater (Gendron and Dallaire 1992, Gendron and Grégoire 2009).

Before the start of each fishing season, all participants received a logbook to record the required information. The first part of the book consisted of full instructions for properly completing each section of the daily logbook. These instructions were also explained at annual meetings between fishers and DFO scientists before the opening of the fishery.

The form consisted of four sections: Fisher identification, Weather, Daily logbook and Experimental traps (Figure 2). The "Daily logbook" section was to collect information on the fisher's commercial fishing activities. This section contained the date, the number of traps hauled, soak time and an estimate of the total weight of commercial-size lobster caught for all traps hauled. Daily weather also had to be recorded (wind speed and direction, cloud cover). The "Experimental traps" section was to collect information on lobsters caught by the four experimental traps, the geographic position (latitude, longitude) and the soak time of traps, as well as the size and category of lobsters caught.

Lobsters were measured using a graduated gauge (Figure 3) divided into 12 (2007 to 2008) and 14 (2009 to 2011) size classes to identify pre-recruits (sizes 1 to 4), commercial-size lobsters (sizes 5 to 12) and jumbo lobsters (sizes 13+) (Table 2). Size classes made it possible to differentiate pre-recruit lobsters from recruits with a limit of 82 mm, which corresponds to the minimum catch size in effect during the study. The pre-recruit group was divided into two sub-groups: pre-recruits 1 (size 4: lobsters that are one moult below recruitment to the fishery) and pre-recruits 2 (sizes 1 to 3: lobsters that are

more than one moult below recruitment to the fishery) (Table 2). Commercial-size lobsters are from classes ≥ 5, among which are the new recruits to the fishery (class 5 for females and classes 5 and 6 for males). In general, size classes 3 to 5 (females) and 3 to 6 (males) correspond to moulting classes, based on growth rates reported by Gendron and Gagnon (2001). Size classes 13 (150 to 155 mm) and 14 (> 155 mm) were added in 2009 and correspond to maximum catch sizes in effect in 2009 (155 mm), 2010 and 2011 (150 mm).



Pêches et Océans Canada / Fisheries and Oceans Canada

Formulaire HOMARD Casiers expérimentaux –*Form LOBSTER (experimental traps)*

IDENTIFICATION | **MÉTÉO**

Bateau / *Vessel* _____ | Acheteur / *buyer* _____ Code _ _ _ _ _ _ _ _ _ | wind (knots) / *speed (knots)* 0 5 10 15 20 25 30 35+

Capitaine / *Captain* _____

NEB /*VRN* _____

Zone de pêche/Fishing area _____ | Formulaire No

Protégé — **JOURNAL DE BORD QUOTIDIEN / *DAILY LOGBOOK*** — ***Protected***

Date	Nombre de casiers *Number of traps*	Temps d'immersion (jours) *Soak time (days)*	Capture (lbs) *Catch (pounds)*
_____	_____	_____	_____

CASIERS EXPÉRIMENTAUX / *EXPERIMENTAL TRAPS*

Temps d'immersion (jours) *Soak time (days)*	Position LATITUDE Deg ____ °Min ____ 'Sec ____ "N	Position LONGITUDE Deg ____ °Min ____ 'Sec ____ "W

RÉGULIER /*REGULAR*			MODIFIÉ/*MODIFIED*			RÉGULIER/*REGULAR*			MODIFIÉ/*MODIFIED*		
M	F	FO/*BF*	M	F	FO/*BF*	M	F	FO/*BF*	M	F	FO/*BF*

Signature de l'exploitant (détenteur du permis ou de son représentant autorisé) *Operator's signature (license holder or his authorized representative)*

Original (bleu) pour le Ministère. Copie blanche pour le pêcheur. Copie jaune pour les Sciences / *Original (blue) for DFO. White copy for fisherman. Yellow copy for Sciences*

Figure 2. Copy of the logbook form completed on a daily basis by the fishers participating in the project.

The gauge was placed parallel to the lobster's dorsal line by pressing the tip of the gauge in the hollow of the eye orbit (Figure 3). The end of the carapace (Figure 3) was aligned with the gauge and the indicated size class was recorded. The size class of every lobster caught in each of the four experimental traps was entered in the appropriate lobster

category column, M: male, F: female and BF: berried female, with each value in the table corresponding to an individual. After the measurements were taken, commercial-size lobsters were kept by the fisher and the others (berried females, pre-recruits and those beyond the maximum size) were released.

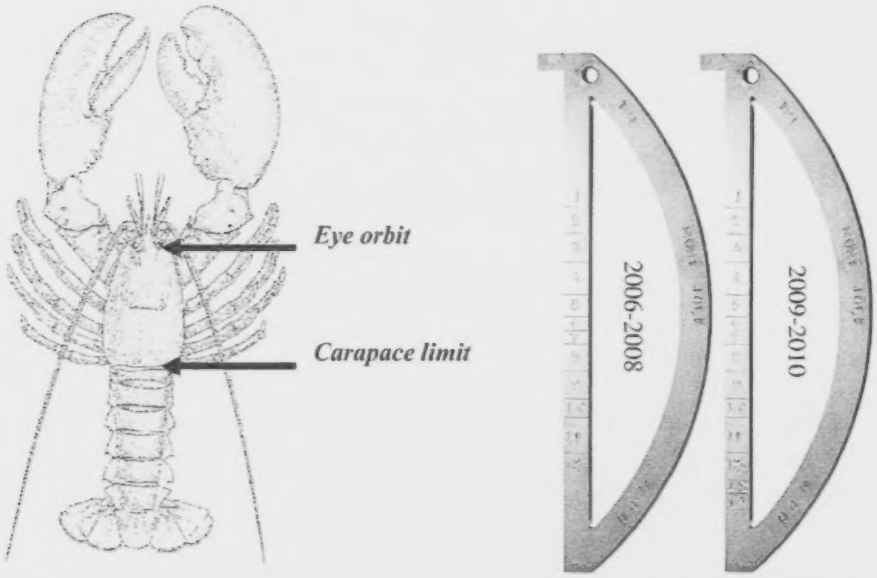


Figure 3. Photograph of the gauge used by fishers to measure lobsters (carapace size) according to 12 (2007 to 2008) or 14 (2009 and 2011) size classes.

Table 2. Carapace length (mm) and categories of lobster based on the gauge's various size classes 1 to 12 (2007 to 2008) and 1 to 14 (2009 to 2011).

Size classes (gauge)	Size (Carapace length, CL)	Lobster categories
1	$x < 50$ mm	
2	$50 \leq x < 60$ mm	Prerecruits 2
3	$60 \leq x < 70$ mm	
4	$70 \leq x < 82$ mm	Prerecruits 1
5[1]	$82 \leq x < 90$ mm	
6[1]	$90 \leq x < 95$ mm	
7	$95 \leq x < 100$ mm	
8	$100 \leq x < 110$ mm	Commercials
9	$110 \leq x < 120$ mm	
10	$120 \leq x < 127$ mm	
11[2]	$127 \leq x < 140$ mm	
12	($\geq$ 140 mm) / $140 \leq x < 150$ mm	
13	$150 \leq x < 155$ mm	Large size
14	$x \geq 155$ mm	

[1] Size classes of fishery recruits: females (5) and males (5 and 6)
[2] Size from which lobsters are usually called "Jumbos" in the industry.

2.2 INFORMATION COLLECTED

The "Weather" section of the daily forms was generally ignored by participants and the information recorded was often incomplete and even completely missing in some cases. This information was therefore not used in this study. The "Daily logbook" section was adequately completed (i.e., > 85% of fishing days) by about three-quarters of the fishers (Table 3). Over the program's five years, an average of 86% of fishers filled out this section. These data will not be covered in this document.

The "Experimental traps" section was well completed. The Table 4 shows the total number (regular + modified) of traps hauled from 2007 to 2011 in each sub-area. Participation was relatively consistent, with the exception of 2010 where the number of participants decreased significantly, from 27 fishers in 2009 to 22 in 2010 (Figure 4). The number of sub-areas covered varied between 15 and 18 from 2007 to 2011. The number of fishers who participated in the experimental sampling each year (2007 to 2011) is 16 (Figure 4). Efforts to recruit fishers were required every year to maintain a sufficient number of participants.

The training given to the fishers before the start of the fishing season and the subsequent telephone calls suggest that the absence of data for a trap means that there were no lobsters in the trap. In this study, we assumed that there were no omissions.

Finally, with regard to the geographic position noted in this section, more than half the fishers did not enter any data (Table 3). However, those who entered geographic coordinates did it on average over more than half the season (57% in 2007, 66% in 2008, 59% in 2009, 55% in 2010 and 73% in 2011).

Table 3. Percentage of fishers (number in parentheses) who provided the information requested in the form for each year: fishers who provided the daily commercial catch weight for at least 85% of fishing days in the season, fishers who did not record any data on their daily catch and fishers who did not provide any position data (latitude and longitude).

Year	Weight of commercial capture		Coordinates
	≥ 85% of fishing days	No data	No data
2007	74 (20)	15 (4)	52 (14)
2008	72 (18)	12 (3)	48 (12)
2009	85 (23)	7 (2)	59 (16)
2010	82 (18)	9 (2)	50 (11)
2011	69 (11)	25 (4)	37 (10)
Average	76%	14%	49%

Table 4. Total number of experimental traps hauled (regular + modified) for each fishery sub-area from 2007 to 2011. The number of regular and modified traps hauled was the same.

Fishery subareas	2007	2008	2009	2010	2011
19C1	104	120	140	148	180
20A1			244	80	236
20A2	192	136	232	244	260
20A3A	260	140	216		
20A4	480	412	200	244	392
20A5	404	240	408	444	416
20A6	452	308	224	240	208
20A7	220	176	220	200	220
20A8	484	244	444	440	432
20A9	636	340	452	480	568
20A9A	368	328	324	196	428
20A10	420		236		256
20B1	440	432	496	496	488
20B2	492	408	252	196	256
20B3	268	248	508	528	520
20B4	240	316	456	440	432
20B5	256	224	240	236	256
20B6			328	232	228
Total	5716	4072	5620	4844	5776

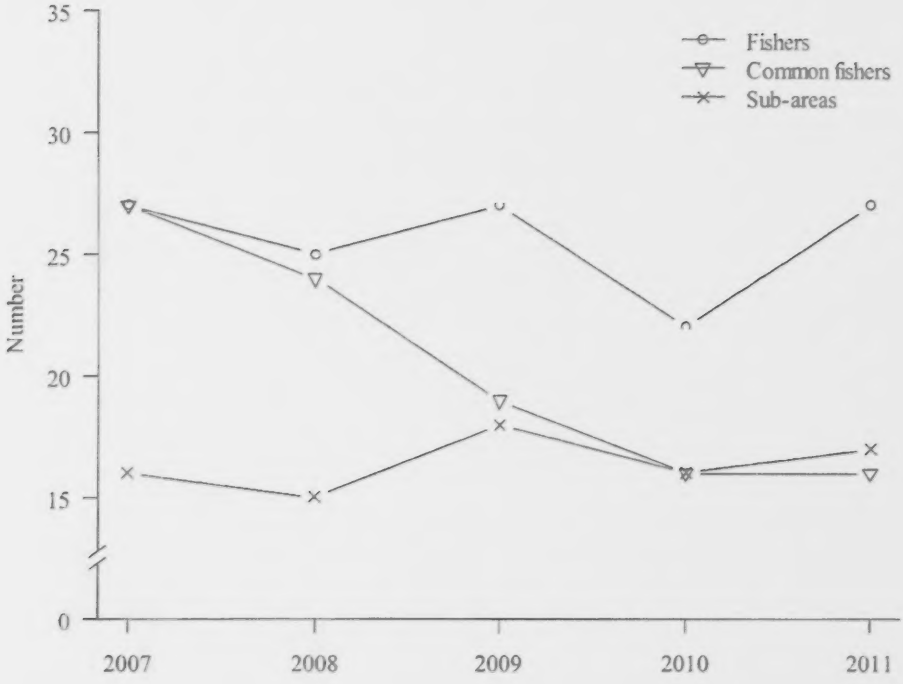


Figure 4. Evolution of participation in the sampling campaign with experimental traps from 2007 to 2011: total number of fishers (Fishers) each year, number of fishers who participated over the last five years (Common fishers) and number of sub-areas sampled by year (Sub-areas).

2.3 DATA ANALYSIS

2.3.1 Spatio-temporal variations in abundance

The data were analyzed to highlight the differences in the abundance of various lobster categories (COM, PRE1, PRE2 and BF) between the sub-areas for a given year and between years within the same sub-area. The analysis was based on catches per unit of effort (CPUE) in numbers of lobsters per trap (regular or modified according to lobster category). The calculation of CPUE and the analysis procedure was developed to reflect an unbalanced sampling plan and data with many zero values. The method used here provided a statistical analysis while respecting the conditions of its application.

The data collected on a daily basis were grouped by week and by period (section 2.3.1.1). A three-factor ANOVA was calculated and the CPUEs per sub-area and per year were calculated (marginal means or "lsmeans" in SAS terminology) (section 2.3.1.2). These mean CPUEs were used for multiple comparisons (section 2.3.1.2).

Data analysis was also performed to show more global interannual trends at the level of Areas 20A and 20B (section 2.3.1.3).

2.3.1.1 Data processing

The data came from experimental traps, half of which were regular traps and half of which were modified. Logbooks were collected by DFO and the data were then entered, validated and analyzed by DFO with Excel 2010 (Microsoft 2010) and R 2.14.1 (R Development Core Team 2012). For each year, catches per unit effort (CPUEs) in numbers of lobsters per trap were calculated for the following lobster categories:

- Commercial (COM): size classes 5 to 12 excluding berried females
- Pre-recruits 1 (PRE1): size class 4
- Pre-recruits 2 (PRE2): size classes < 4
- Berried females (BF): all size classes

The abundance of the different categories of lobster was studied using two types of traps, based on their catch effectiveness for the category (see section 3.1). The abundance of COM was therefore analyzed using the regular traps, while the abundance of PRE1, PRE2 and BF was analyzed using the modified traps.

First, each year, a weekly CPUE was calculated by sub-area according to the following equation:

$$\overline{CPUE}_i = \frac{\sum_{j=1}^{n_i} \left(\frac{\sum catch_{ji}}{\sum effort_{ji}} \right)}{n_i}$$

where i is the week, j is the fisher and n_i is the number of fishers having fished during the week i. The use of the weekly CPUE rather than the daily CPUE helped reduce the number of zeros and thus facilitate analyses. Depending on the year, the daily CPUE equal to zero ranged from 30 to 48% for COM, 15 to 40% for PRE1, 17 to 68% for PRE2 and 51 to 73% for BF. The compilation of data on a weekly basis (7 days) eliminated almost all zeros.

The weekly CPUEs calculated by sub-area and year are presented in Appendices 1 to 4 for the four lobster categories. In general, CPUEs are not constant and vary during the fishing season. COM show a decrease over time, whereas PRE1, PRE2 and BF show the opposite. It should be noted that the sampling plan was unbalanced in the sense that, in some years, weeks were not all well-represented in some sub-areas, especially at the beginning or end of the fishing season. This lack of data may cause a bias in the calculation of an annual CPUE for a sub-area when it is based simply on the arithmetic mean of weekly CPUEs. For example, when there is a negative trend in CPUE over time, the annual mean will be underestimated for a sub-area missing the first week, while it will be overestimated for a sub-area missing the last week. To minimize this bias, without necessarily eliminating it, we combined the weekly CPUEs into two (beginning and end of season) five-week periods. The factor "Period" was included in the variance analysis (see next section) to calculate an annual CPUE based on equal representation of the two fishing periods. This procedure reduces the bias on the mean that could be caused by the lack of data for a week of fishing.

2.3.1.2 Analyses of Variance

Data were analyzed by a three-factor ANOVA (analysis of variance): Year, Area and Period. Factor levels were as follows:

Year: 2007 to 2011

Area: 20A4, 20A5, 20A6, 20A7, 20A8, 20A9, 20A9A, 20B1, 20B2, 20B3, 20B4, 20B5

Period: 1 (Start) and 2 (End)

This analysis was done on the weekly CPUEs of the different categories of lobster (calculated as described in section 2.3.1.1) using the function *lm {stats}* and *Anova {car}* (Fox and Weisberg 2011) in R, which together are used to calculate a type III analysis of variance table.

The calculation of the annual CPUE for a sub-area was based on the marginal mean (lsmeans according to SAS terminology) where an equal weight was given to each period. The calculation was made per year for each sub-area based on the following equations:

$$\overline{CPUE}_p = \frac{\sum \overline{CPUE}_i}{k}$$

where p is the period, i the week and k the number of weeks in the period ($3 \leq k \leq 5$).

$$\overline{CPUE} = \frac{\sum \overline{CPUE}_p}{n}$$

where p is the period and n, which represents the number of periods, equals 2.

The effect of the factor "Period" was therefore used in the calculation of the mean annual CPUE for each sub-area (marginal mean). This factor was integrated in the model to remove it's effect so the analysis could proceed for the main factors Year and Area along with their interactions. Results are interpreted the same way as for a two-way ANOVA.

The mean CPUE calculated this way were used for multiple comparisons. They are less affected by the lack of data and produce less biased comparisons than using arithmetic means. In addition, only the sub-areas with sufficient data were retained. Therefore, for a sub-area to be used, there must have been at least 60% of fishing weeks for each period of the season (i.e., at least three weeks out of five), and for each year. From the 15 to 18 sub-areas covered between 2007 and 2011, 12 sub-areas were selected. Multiple two-by-two comparisons (contrast tests) were conducted using Student's t-tests. The "p" values were corrected with the Holm adjustment (Holm 1979) to keep the alpha error risk at 0.05 for all comparisons. Comparisons of interest were the interannual differences by sub-area and the intra-annual differences between sub-areas.

The Brown-Forsythe (1974) analysis was used to verify the homoscedasticity of residuals between the different factor levels and, if needed, different exponential or logarithmic transformations were used to obtain it. Residual normality was then tested using the D'Agostino-Pearson omnibus test, (D'Agostino and Pearson 1973) which is preferable to the Shapiro-Wilk test when there are multiple data with the same value (Thode 2002, Zar 2010). A residual frequency histogram was also used in parallel with the D'Agostino-Pearson test to examine the data visually. When the distribution of residuals was statistically different from the normal distribution, but the asymmetry index was not significantly different from zero, the ANOVA results were used as long as the distribution of residuals was not visually bimodal. This choice is based on the fact that the analysis of variance is relatively robust to non-normality (Quinn and Keough 2002).

Finally, abundance differences for the four lobster categories between sub-areas were also examined by comparing them with the 25th, 50th (median) and 75th percentiles for all the mean CPUE values.

2.3.1.3 Overall trends

Following the ANOVA, the temporal trend for the entire LFA 20 (20A and 20B combined) was studied for the four lobster categories (COM, PRE1, PRE2 and BF) using linear regression analyses. LFA 20 was represented by a mean annual CPUE corresponding to the mean of the annual CPUEs of the sub-areas (section 2.3.1.2). Only the slopes were examined in this part of the study as the intercepts had no biological meaning.

2.3.2 Spatio-temporal structure

Correlation analyses were done to determine whether the spatial structure observed in the distribution of each category of lobster was constant for consecutive years. Correlation analyses were used on annual CPUE (natural logarithm) (2007 to 2011) for each sub-area selected for analysis.

2.3.3 Forecasting tool of the recruitment to the fishery

The potential to predict the abundance of larger lobsters from the smaller size lobsters was examined using type I regression analyses (least squares method). Relationships were estimated between lobster categories COM, PRE1 and PRE2 from the mean CPUE estimated by sub-area. It is assumed that, based on the growth rate and molting frequency, PRE1 lobsters of a given year will be in the COM category the following year, and that PRE2 will be in the PRE1 category a year later and in the COM category two years later. To better emphasize relationships, females were excluded and the number of size classes was limited (i.e., COM: classes 5 to 6, PRE1: class 4 and PRE2: class 3). The relationships between size classes thus correspond to relationships between successive moult classes. The COM class is therefore restricted to new recruits to the fishery. Regressions were calculated for consecutive years (COM vs. PRE1 and PRE1 vs. PRE2) or two-year intervals (COM vs. PRE2). The analyses were conducted separately for 20A and 20B. First, the calculation was based on individual data for each sub-area (annual CPUE) to show the variability in the sub-area and eventually make forecasts for the sub-area. Regressions were then calculated from the mean values of 20A and 20B (mean of CPUEs for sub-areas) to make overall forecasts for Areas 20A and 20B.

3.0 RESULTS

3.1 Overview

During the five-year project (2007 to 2011), between 4072 and 5776 traps were hauled each year (sum of modified and regular traps) and between 11 917 and 18 428 lobsters were measured annually. Non-berried females represented between 44 and 47% of total catches, which is slightly higher than the proportion consisting of males, which represented between 38 and 43% (Figure 5). In general, lobsters of size classes 3 and 4 dominated the catches by modified traps and size classes 3, 4 and 5 by regular traps, representing 69 and 78% respectively of total catches. Of all the lobsters caught in 2009 and 2010 (around 28 000), no lobsters larger than the maximum catch size (2009: 155 mm; 2010: 150 mm) were caught. However, in 2011, 10 of the 18 428 lobsters caught were larger than the maximum catch size (150 mm). The proportion of berried females was fairly constant from 2007 to 2009 (11 to 13%) and has increased over the last two years (14 and 16%) (Figure 6). The use of modified traps highlighted the presence of berried females whose size is less than the minimum catch size of 82 mm (size classes ≤ 4). The modified traps also seemed to be more effective for catching berried females of size classes 5 and 6.

An overall annual CPUE was calculated (all lobsters caught/all traps, l/t) for each lobster category based on the trap type. As expected, the use of modified traps helped catch more small lobsters (size classes 1 to 4) than regular traps (Figures 5 and 6). CPUEs of pre-recruits 1 and 2 (PRE1 and PRE2) but also of berried females (BF) were higher in the modified traps (Table 5). For PRE1, CPUEs were 1.20 l/t and 0.74 l/t for modified and regular and traps respectively (Table 5). For berried females (BF), CPUEs were 0.43 l/t and 0.30 l/t for modified and regular traps respectively (Table 5). On average, for the five years of the study, the modified traps caught 2.86 times more PRE2, 1.62 more PRE1 and 1.41 more BF than regular traps (Table 5). For catching commercial-size lobsters (COM), the modified traps (0.57 l/t) appeared somewhat less effective than regular traps (0.66 l/t) (Table 5). Catches made with modified traps averaged 0.86 times that of regular traps.

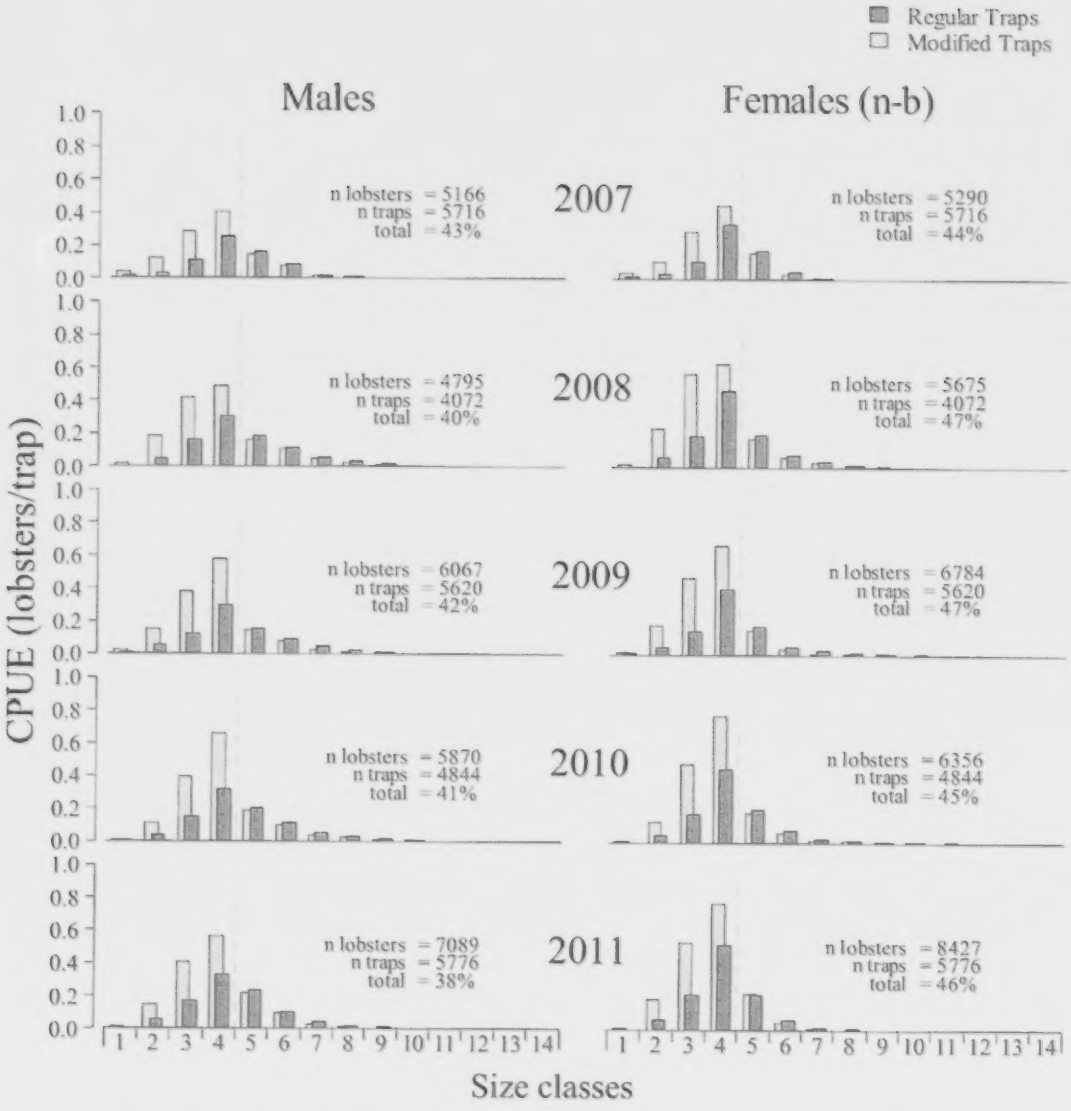


Figure 5. Overall annual CPUEs for males and non-berried females (n-b) (total number of lobsters caught/total number of traps) by size class based on the type of trap for 2007 to 2011. The dotted gray line separates pre-recruit lobsters from commercial-size lobsters. For each year and each category, the number of lobsters, the total number of traps hauled and the percentage of males and n-b females observed in the total catch of the year are shown.

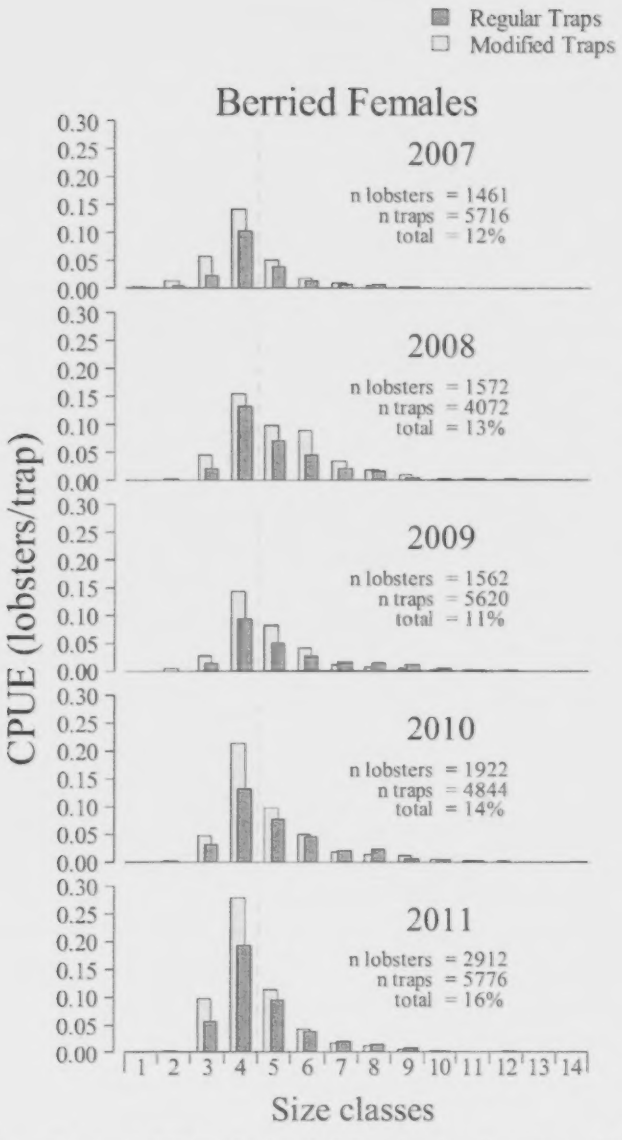


Figure 6. Overall annual CPUEs for berried females (total number of lobsters caught/total number of traps) by size class based on the type of trap for 2007 to 2011. The dotted gray line separates pre-recruit lobsters from commercial-size lobsters. For each year and each category, the number of lobsters, the total number of traps hauled and the percentage of berried females observed in the total catch of the year are shown.

Table 5. Overall annual CPUEs for lobster (total number of lobsters/total number of traps) for pre-recruits 2 (size classes 1 to 3) and 1 (size class 4), commercial-size lobsters (size classes 5 to 13 excluding berried females) and berried females. Mean values are estimated by trap type (regular and modified). Column M/R is the ratio between the CPUE for modified traps and the CPUE for regular traps.

Year	Prerecruits 2			Prerecruits 1			Commercials			Egg-bearing Females		
	Regular	Modified	M/R	Regular	Modified	M/R	Regular	Modified	M/R	Regular	Modified	M/R
2007	0.33	0.89	2.70	0.59	0.85	1.44	0.52	0.47	0.90	0.21	0.30	1.43
2008	0.46	1.43	3.11	0.77	1.12	1.45	0.73	0.64	0.88	0.31	0.46	1.48
2009	0.38	1.21	3.18	0.70	1.24	1.77	0.59	0.47	0.80	0.23	0.33	1.43
2010	0.40	1.11	2.77	0.77	1.43	1.86	0.73	0.61	0.84	0.34	0.46	1.35
2011	0.51	1.30	2.55	0.85	1.34	1.58	0.72	0.65	0.90	0.43	0.58	1.35
Average	0.42	1.19	2.86	0.74	1.20	1.62	0.66	0.57	0.86	0.30	0.43	1.41

3.2 SPATIO-TEMPORAL VARIATIONS IN ABUNDANCE (CPUE)

3.2.1 Analyses of Variance

An ANOVA was used for each category of lobster to estimate the proportion of variance in CPUE that could be explained by the three main factors and their interactions. Data transformation helped meet the homoscedasticity condition. However, the data from COM, PRE1 and PRE2 could not be normalized with the transformations. The ANOVA results were nevertheless used as the skewness coefficient was not significantly different from zero (Table 6).

Table 6. Results of analyses verifying the ANOVA conditions for each category of lobster. "Trans" are the mathematical transformations applied to the data, where "y" is the dependent variable. B-F is the "p" value from the Brown-Forsythe test. Values of "p" to test asymmetry, kurtosis and the D'Agostino-Pearson omnibus test are also presented.

Category	Trans	B-F	D'Agostino-Pearson		
			Skewness	Kurtosis	Omnibus
COM	$y^{0.44}$	0.8197	0.9953	< 0.0001	0.0002
PRE1	$y^{0.7}$	0.3301	0.1980	0.0007	0.0033
PRE2	$y^{0.6}$	0.3047	0.1794	< 0.0001	0.0001
BF	$y^{0.5}$	0.6897	0.3485	0.0716	0.1853

The results from the three-factor ANOVA (Year, Area and Period) are presented in Table 7. As mentioned in section 2.3.1, the results for the Period factor will not be analyzed here because the effect of this factor was included in the annual mean. The following analyses therefore focus on the factors Year and Area only.

Table 7. Results of the 3-factor ANOVA analysis (Area, Year and Period) performed on the CPUEs of the different categories of lobster (COM, PRE1, PRE2 and BF).

Category	Source	df	Type III SS	Mean sq. root	F	Pr > F
COM	area	11	7.830	0.710	17.49	< 0.0001
	year	4	2.070	0.520	12.73	< 0.0001
	area*year	44	5.950	0.140	3.32	< 0.0001
	per[1]	1	7.720	7.720	189.61	< 0.0001
	area*per[1]	11	2.040	0.190	4.55	< 0.0001
	year*per[1]	4	1.280	0.320	7.86	< 0.0001
	area*year*per[1]	44	2.700	0.060	1.51	0.0227
	residuals	463	18.840	0.040		
PRE1	area	11	106.570	9.690	85.29	< 0.0001
	year	4	10.690	2.670	23.53	< 0.0001
	area*year	44	18.970	0.430	3.8	< 0.0001
	per[1]	1	9.420	9.420	82.91	< 0.0001
	area*per[1]	11	16.380	1.490	13.11	< 0.0001
	year*per[1]	4	3.740	0.940	8.23	< 0.0001
	area*year*per[1]	44	7.930	0.180	1.59	0.0119
	residuals	463	52.590	0.110		
PRE2	area	11	24.350	2.210	31.68	< 0.0001
	year	4	6.110	1.530	21.87	< 0.0001
	area*year	44	15.360	0.350	4.99	< 0.0001
	per[1]	1	1.840	1.840	26.34	< 0.0001
	area*per[1]	11	1.130	0.100	1.48	0.1372
	year*per[1]	4	2.240	0.560	8	< 0.0001
	area*year*per[1]	44	6.970	0.160	2.27	< 0.0001
	residuals	463	32.350	0.070		
BF	area	11	17.740	1.610	37.99	< 0.0001
	year	4	3.450	0.860	20.33	< 0.0001
	area*year	44	9.990	0.230	5.35	< 0.0001
	per[1]	1	5.400	5.400	127.19	< 0.0001
	area*per[1]	11	0.860	0.080	1.84	0.0453
	year*per[1]	4	0.770	0.190	4.52	0.0014
	area*year*per[1]	44	2.560	0.060	1.37	0.0614
	residuals	463	19.650	0.040		

[1] Results concerning the factor PER (Period) and all interactions including it are in grey. These results are not interpreted since inclusion of PER had for sole purpose the estimation of marginal means for years and areas.

3.2.1.1 Commercial (COM)

Figure 7 shows the mean CPUE for COM for each sub-area and per year. The corresponding values are found in Appendix 5. ANOVA results show that the two-way interaction (Year * Area) was significant (i.e., $p < 0.05$) (Table 7). The multiple comparisons analysis conducted on CPUEs shows no significant interannual difference (intra sub-area) for 8 of the 12 sub-areas analyzed (Appendix 6). The only significant interannual differences were observed for sub-areas 20A7, 20A9A, 20B2 and 20B5. In recent years, the CPUE for 20A7 (2010: 1.13 l/t), 20B2 (2010: 1.56 l/t; 2011: 0.97 l/t) and 20B5 (2011: 0.77 l/t) have been significantly higher than those from previous years. For sub-area 20A9A, the low value of 2010 (0.27 l/t) differs significantly from those of other years.

The multiple comparisons analysis between sub-areas for each year revealed 39 significant differences, mainly in 2009 (17) and 2010 (13) (Appendix 7). In 2007, 2008 and 2011, sub-areas appeared relatively homogeneous. In 2009, CPUEs in sub-areas 20A4 (0.08 l/t), 20A6 (0.15 l/t), 20B5 (0.17 l/t) were lower than most other sub-areas, while 20A9 (1.18 l/t) had a higher mean CPUE than several other sub-areas. In 2010, the majority (8) of statistically significant differences were for sub-area 20B2, which had a markedly higher CPUE value than other sub-areas.

The 25th and 75th percentile values (2007 to 2011) are 0.36 and 0.73 l/t respectively (Figure 7), or a difference of 0.37 l/t. The mean intra-annual coefficient of variation is 45% and the mean interannual coefficient of variation is 37%. There are six sub-areas (20A5, 20A8, 20A9, 20B1, 20B2 and 20B3) where the mean CPUEs were greater than or equal to the median for at least 50% of the years. Three of these sub-areas (20A5, 20A8 and 20A9) stand out more than the others since the mean CPUEs were greater than or equal to the 75th percentile for at least 50% of the years. Sub-areas where CPUEs were lowest are 20A4, 20A6 and 20B4 with mean CPUEs lower than the 25th percentile for at least 50% of the years.

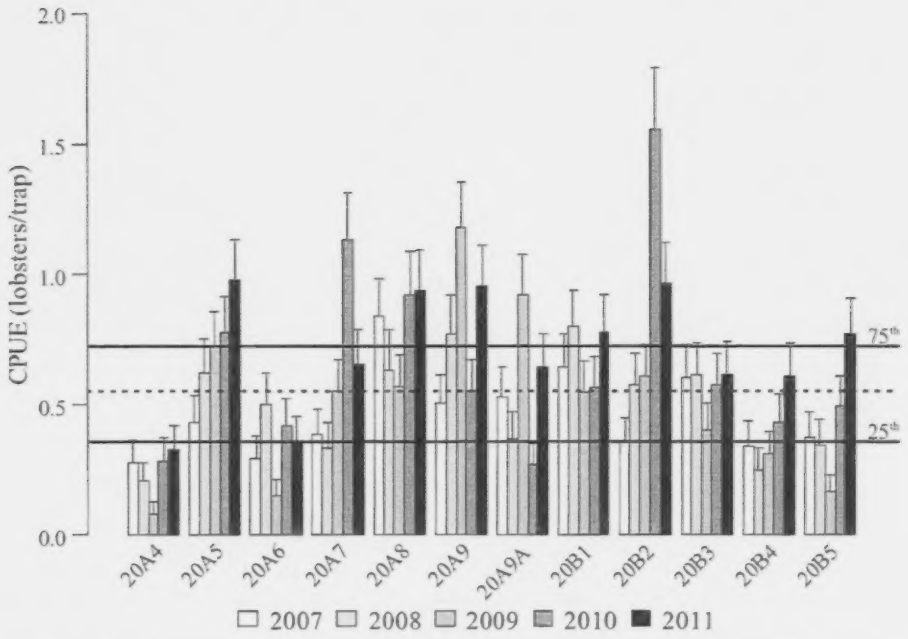


Figure 7. Mean CPUEs in number/trap (+ standard error) of estimated COM per sub-area for 2007 to 2011. The horizontal lines are, respectively from top to bottom, 75th, 50th (median) and 25th percentiles.

3.2.1.2 Pre-recruits 1 (PRE1)

Figure 8 shows the mean CPUEs for PRE1 for each sub-area and per year. The corresponding values are found in Appendix 5. ANOVA results show that the two-way interaction (Year * Area) was significant (Table 7). The multiple comparisons analysis conducted on CPUEs shows no significant interannual difference (intra sub-area) for 7 of the 12 sub-areas analyzed (Appendix 8). Significant interannual differences were observed for sub-areas 20A5, 20A8, 20B2, 20B4 and 20B5. For sub-areas 20A5 and 20A8, the 2007 season stands out with a lower CPUE than for subsequent years with 1.31 l/t and 1.47 l/t, respectively. In recent years, the CPUEs in 20B2 (2011: 1.89 l/t), 20B4 (2010: 3.20 l/t; 2011: 3.06 l/t) and 20B5 (2010: 2.49 l/t; 2011: 2.83 l/t) were significantly higher than those from previous years.

There is greater inter-area heterogeneity for PRE1 than for COM. The analysis of multiple comparisons between sub-areas for the different years showed 148 significant differences with 16 in 2007, 36 in 2008, 32 in 2009, 32 in 2010 and 31 in 2011

(Appendix 9). In 2007, the differences mainly concerned sub-areas 20A9A (2.15 l/t) and 20B4 (2.18 l/t), which had much higher CPUE values than the other sub-areas. From 2008 until 2010, there is a clear separation between sub-areas with high and low values. There are six sub-areas with high CPUEs: 20A9A and 20B4 (as in 2007) and 20A5, 20A8, 20A9 and 20B5. In these sub-areas, CPUEs were always higher than 1.50 l/t, with a mean of 2.26 l/t and a maximum of 3.20 l/t in 20B4 in 2010. In contrast, for the 2008 to 2010 period, sub-areas 20A4, 20A6, 20A7, 20B1, 20B2 and 20B3 always had lower CPUEs. In these sub-areas, CPUEs remained generally lower than 1.50 l/t, with a mean of 0.82 l/t. However, in 2011, CPUEs were much higher for 20A7, 20B1 and 20B2. Sub-areas that statistically stand out the most in 2011 are 20A5 (2.82 l/t), 20A9A (2.92 l/t), 20B4 (3.06 l/t) and 20B5 (2.83 l/t) for their high abundance, while 20A4 (0.70 l/t) and 20A6 (0.54 l/t) have the lowest CPUEs.

The 25th and 75th percentile values (2007 to 2011) are 0.75 and 2.15 l/t respectively (Figure 8), or a difference of 1.40 l/t. The mean intra-annual coefficient of variation is 51% and the mean interannual coefficient of variation is 28%. There are six sub-areas (20A5, 20A8, 20A9, 20A9A, 20B4 and 20B5) where the mean CPUEs were greater than or equal to the median for at least 50% of the years. Three of these sub-areas (20A5, 20A9 and 20B4) stand out more than the others since the mean CPUEs were greater than or equal to the 75th percentile for at least 50% of the years. Sub-areas where CPUEs were lowest are 20A4, 20A6, 20A7 and 20B2 with mean CPUEs lower than the 25th percentile for at least 50% of the years.

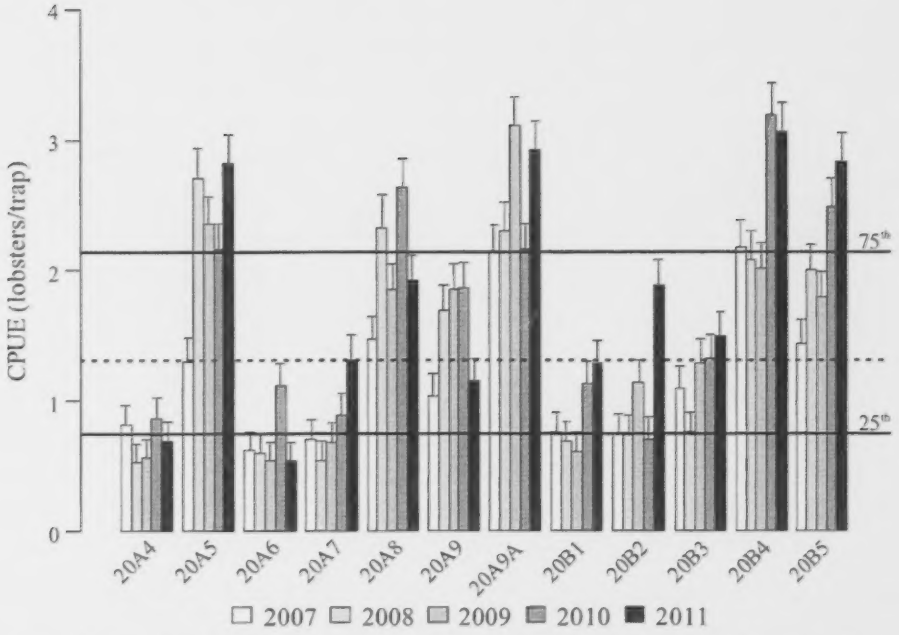


Figure 8. Mean CPUEs in number/trap (+ standard error) of estimated PRE1 per sub-area for 2007 to 2011. The horizontal lines are, respectively from top to bottom, 75th, 50th (median) and 25th percentiles.

3.2.1.3. Pre-recruits 2 (PRE2)

Figure 9 shows the mean CPUEs for PRE2 for each sub-area and per year. The corresponding values are found in Appendix 5. ANOVA results show that the two-way interaction (Year * Area) was significant (Table 7). The multiple comparisons analysis done on CPUEs shows no significant interannual difference (intra sub-area) for 5 of the 12 sub-areas analyzed (Appendix 10). Significant interannual differences were observed for sub-areas 20A9, 20A9A, 20B1, 20B2, 20B3, 20B4 and 20B5. For sub-areas 20A9 and 20B3, the 2007 season stands out with a lower CPUE than for subsequent years with 0.55 l/t and 0.79 l/t, respectively. In recent years, the CPUEs in 20B1 (2011: 2.08 l/t), 20B5 (2010: 2.79 l/t; 2011: 2.85 l/t) were significantly higher than those from previous years. For 20A9A, CPUE in 2008 stand out from other years as the highest (2.51 l/t). In sub-area 20B2, there was a marked decrease (79%) in CPUE between 2009 (1.03 l/t) and 2010 (0.22 l/t).

The abundance of PRE2 appears less heterogeneous than PRE1, but greater than COM. The analysis of multiple comparisons between sub-areas for the different years showed 78 significant differences with 6 in 2007, 16 in 2008, 10 in 2009, 21 in 2010 and 25 in 2011 (Appendix 11). In 2007, the differences mainly concerned sub-areas 20A6 (1.57 l/t) and 20B4 (1.51 l/t), which had higher CPUE values than most other sub-areas. For the 2008 season, sub-areas 20A7 (1.42 l/t), 20A9A (2.51 l/t), 20B4 (1.85 l/t) and 20B5 (2.13 l/t) had higher CPUEs than most other sub-areas. In 2009, sub-areas 20A4 (1.85 l/t), 20A6 (1.98 l/t) and 20A7 (2.28 l/t) had high CPUEs values compared to several other sub-areas. During the 2010 season, sub-area 20B5 (2.79 l/t) stood out from other sub-areas with its high value, while 20B2 also stood out from the others because of its low value (0.22 l/t). Finally, in 2011, sub-areas 20A6 (2.29 l/t), 20A7 (2.13 l/t), 20B1 (2.08 l/t) and 20B5 (2.85 l/t) had higher CPUEs than most other sub-areas, while 20A5 (0.92 l/t), 20A8 (0.98 l/t), 20B2 (0.73 l/t) and 20B4 (0.96 l/t) were characterized by lower CPUEs than most other sub-areas.

The 25th and 75th percentile values (2007 to 2011) are 0.98 and 1.57 l/t respectively (Figure 9), or a difference of 0.77 l/t. The mean intra-annual coefficient of variation is 37% and the mean interannual coefficient of variation is 29%. There are six sub-areas (20A4, 20A6, 20A7, 20A9A, 20B3 and 20B5) where the mean CPUEs were greater than or equal to the median for at least 50% of the years. Three of these sub-areas (20A6, 20A7 and 20B5) stand out more than the others since the mean CPUEs were greater than or equal to the 75th percentile for at least 50% of the years. The sub-area where CPUEs were lowest was 20B2 with mean CPUEs lower than the 25th percentile for at least 50% of the years.

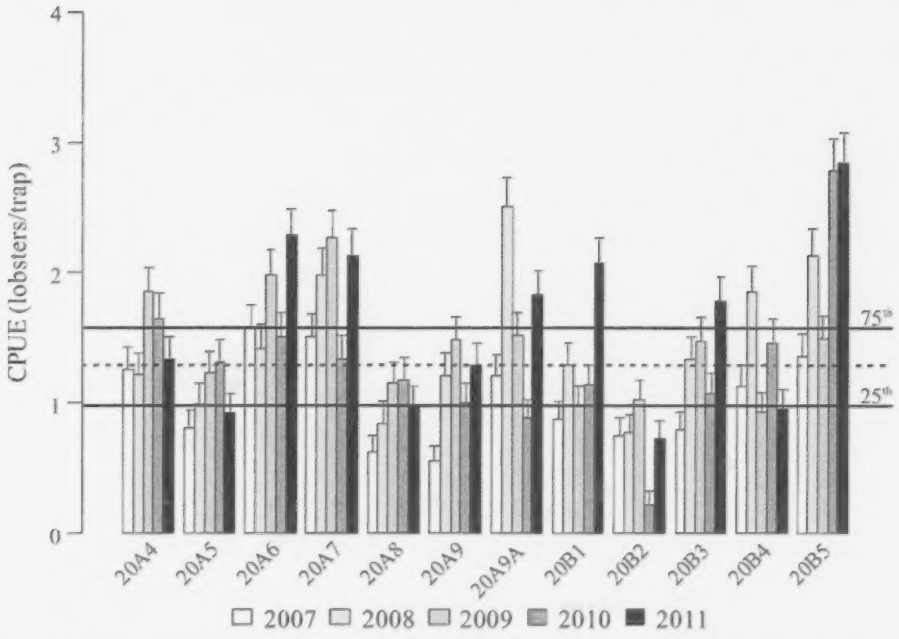


Figure 9. Mean CPUEs in number/trap (+ standard error) of estimated PRE2 per sub-area for 2007 to 2011. The horizontal lines are, respectively from top to bottom, 75th, 50th (median) and 25th percentiles.

3.2.1.4. Berried Females (BF)

Figure 10 shows the mean CPUEs for BF for each sub-area and per year. The corresponding values are found in Appendix 5. ANOVA results show that the two-way interaction (Year * Area) was significant (Table 7). The multiple comparisons analysis done on CPUEs shows no significant interannual difference (intra sub-area) for 5 of the 12 sub-areas analyzed (Appendix 12). Sub-areas with significant interannual differences are 20A4, 20A6, 20A7, 20A9, 20B1, 20B2 and 20B3. For 20A4, CPUE in 2010 (0.87 l/t) is greater than CPUE in 2007 (0.21 l/t) and 2008 (0.27 l/t). In sub-area 20A6, CPUEs in 2007 (0.88 l/t) were much higher (5 to 10 times) than those of subsequent years (2008: 0.14 l/t, 2009: 0.09 l/t, 2010: 0.18 l/t and 2011: 0.28 l/t). For sub-area 20A7, the major difference was for the very low value in 2010 (0.01 l/t) compared to 2009 (0.27 l/t) and 2011 (0.38 l/t). In sub-areas 20A9 (0.11 l/t), 20B1 (0.78 l/t) and 20B2 (0.10 l/t), CPUEs in 2007 were generally lower than in other years. Finally, in sub-area 20B3, CPUEs in 2011 (0.92 l/t) were significantly higher than those of other years.

The analysis of multiple comparisons between sub-areas for the different years showed 82 significant differences with 18 in 2007, 11 in 2008, 14 in 2009, 24 in 2010 and 15 in 2011 (Appendix 13). In 2007, the differences revealed through analysis mainly concerned sub-areas 20A6 (0.88 l/t) and 20B1 (0.78 l/t), which had higher CPUE values than other sub-areas. In 2008, sub-area 20B1 (1.52 l/t) had a CPUE value higher than all other sub-areas. In 2009, sub-areas 20A6 (0.09 l/t), 20A8 (0.11 l/t) and 20B5 (0.10 l/t) stood out with low CPUEs, while 20B1 (1.09 l/t) stood out as the sub-area with the highest CPUE. In 2010, 20A4 (0.87 l/t) and 20B1 (1.31 l/t) had higher CPUEs than most other sub-areas, while 20A6 (0.18 l/t) and 20A7 (0.02 l/t) had the lowest CPUE. Finally, sub-areas 20B1 (1.61 l/t) and 20B3 (0.92 l/t) stood out from the others with the highest CPUEs.

The 25th and 75th percentile values (2007 to 2011) are 0.19 and 0.45 l/t respectively (Figure 10), or a difference of 0.26 l/t. The mean intra-annual coefficient of variation is 84% and the mean interannual coefficient of variation is 55%. There are six sub-areas (20A4, 20A9, 20A9A, 20B1, 20B2 and 20B4) where the mean CPUEs were greater than or equal to the median for at least 50% of the years. Only one of these sub-areas (20B1) stood out more than the others since the mean CPUEs were always greater than the 75th percentile. Sub-areas where CPUEs were lowest are 20A6, 20A7 and 20A8 with mean CPUEs lower than the 25th percentile for at least 50% of the years.

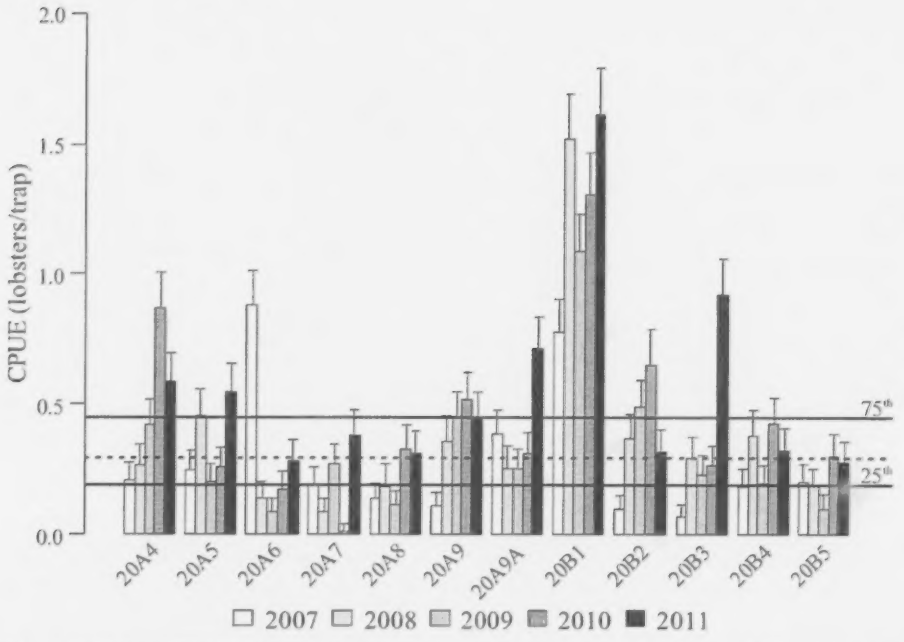


Figure 10. Mean CPUEs in number/trap (+ standard error) of estimated BF per sub-area for 2007 to 2011. The horizontal lines are, respectively from top to bottom, 75th, 50th (median) and 25th percentiles.

3.2.2 Overall trends

The mean CPUE trend in LFA 20 (mean annual CPUEs of sub-areas) based on years (2007 to 2011) is positive and significant for all lobster categories except PRE2 where the slope is positive but not significant (Table 8). The slopes for COM and BF are similar. It is higher for PRE1. The mean CPUEss of PRE1 have increased continuously since 2007 (Figure 11). CPUE for COM and BF increased between 2009 and 2011. They were fairly stable between 2007 and 2009. CPUEs for PRE2 fluctuated but presented no clear trend. In 2011, the mean CPUEs were the highest since 2007 for all categories of lobster.

Table 8. Results of linear regressions calculated between the mean CPUEs of the different categories of lobster for the entire LFA 20 and the year.

Category	Slope	R^2	t	p
COM	0.0627	0.81	3.61	0.0366
PRE1	0.1516	0.98	12.62	0.0011
PRE2	0.0879	0.45	1.55	0.2179
BF	0.0600	0.81	3.63	0.0360

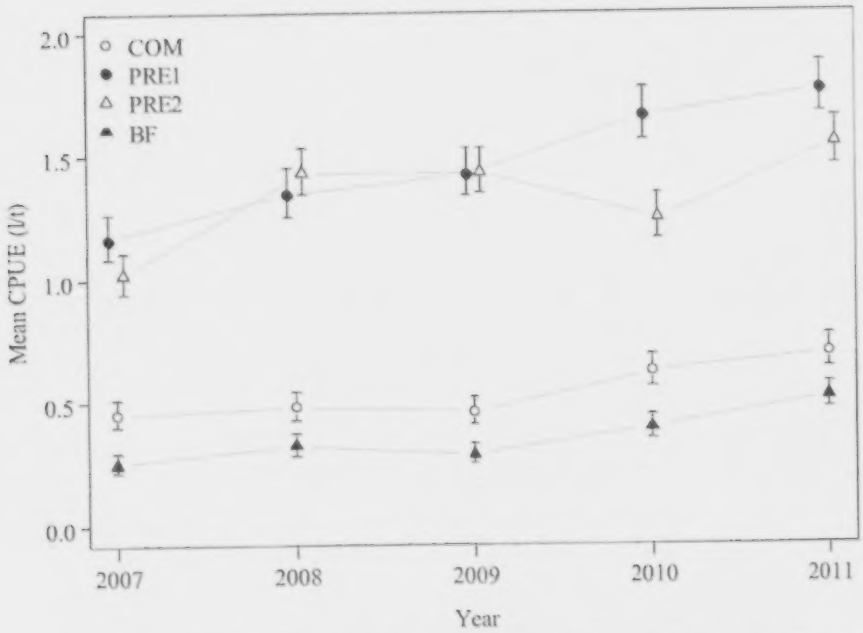


Figure 11. Mean CPUEs in number/trap (± confidence interval) estimated for the four categories of lobster (COM, PRE1, PRE2, BF) from 2007 to 2011.

3.3 Spatio-temporal structure

Review of the multiple comparisons analysis results (Section 3.2.1) suggests the existence of a spatial structure in the distribution of different categories of lobster in the territory covered by the study. The correlation between the abundance of COM category lobsters from different sub-areas between two consecutive years is positive and significant (Table 9; Appendix 14). The same is true for the PRE1 category (Table 9; Appendix 15). These

positive correlations indicate that differences in abundance of COM and PRE1 lobsters between sub-areas are constant over time, at least for 2007 to 2011. This analysis indicates that in the study territory, there are sub-areas where abundance is consistently weaker or stronger than elsewhere. This spatial structure also appears in the PRE2 lobster category, except for 2010 when the abundance of PRE2 appeared relatively homogeneous throughout the area (Appendix 16). There is also a spatial structure for berried females (BF), which was apparent starting in 2008 (Table 9; Appendix 17) and then faded in 2011.

Table 9. Correlation coefficients (r) between the abundance of lobster in the various sub-areas between two consecutive years, for each category of lobster. The "p" value is shown for each correlation coefficient (r).

Category	Years	r	p
COM	2007 - 2008	0.65	0.0218
	2008 - 2009	0.63	0.0290
	2009 - 2010	0.68	0.0215
	2010 - 2011	0.64	0.0262
PRE1	2007 - 2008	0.86	0.0003
	2008 - 2009	0.93	0.0000
	2009 - 2010	0.79	0.0022
	2010 - 2011	0.80	0.0029
PRE2	2007 - 2008	0.69	0.0132
	2008 - 2009	0.64	0.0470
	2009 - 2010	0.16	0.6404
	2010 - 2011	0.33	0.3261
FO	2007 - 2008	-0.14	0.6954
	2008 - 2009	0.71	0.0224
	2009 - 2010	0.88	0.0003
	2010 - 2011	0.47	0.1420

3.4 FORECASTING TOOL OF THE RECRUITMENT TO THE FISHERY

3.4.1. Forecasts – sub-areas

The relationships between the CPUEs for PRE1 in a given year ($PRE1_t$) and COM the following year (COM_{t+1}), between $PRE2_t$ and $PRE1_{t+1}$ and between $PRE2_t$ and COM_{t+2}, for all sub-areas combined, are not significant ($p > 0.05$) (Appendix 18). COM, PRE1 and PRE2 are made up here of males of size classes 5 and 6, 4 and 3, respectively. However, upon closer review of these figures, trends are evident in Areas 20A and 20B. Furthermore, within these areas, some groups of sub-areas also seem to stand out (Figures 12 to 14).

3.4.1.1. Relationships between $PRE1_t$ and COM_{t+1}

There is a positive relationship between $PRE1_t$ and COM_{t+1} for Area 20A (Figure 12A). Moreover, in this area, there is a group of sub-areas (Group I: 20A4, 20A6 and 20A7) where the CPUEs for PRE1 and COM are relatively low and another group (Group II: 20A5, 20A8, 20A9 and 20A9A) where the values are higher (Figure 12A, Appendix 19). For all of Area 20A, the relationship between $PRE1_t$ and COM_{t+1} is positive and significant (Table 10). The variability of COM_{t+1} is explained at 61% by the variability of $PRE1_t$. CPUEs for COM represent approximately 30% of the CPUEs for PRE1 from the previous year. The relationship also tends to be positive between years for each of the 20A sub-areas (Appendix 19A) and for each year (Appendix 19B). The situation is different in Area 20B where a negative relationship is observed between $PRE1_t$ and COM_{t+1} (Figure 12B, Appendix 19D). However, the relationship is non-significant (Table 10). In 20B, there is a group of sub-areas (Group III: 20B1 and 20B2) where the abundance of COM_{t+1} is relatively high despite the low abundance of $PRE1_t$. There is also a group of sub-areas (Group IV: 20B3, 20B4 and 20B5) where COM_{t+1} remain relatively constant regardless of the value of $PRE1_t$ (Figure 12B). The relationship reflects a spatial gradient in the abundance of lobster from 20B1 to 20B5, which is positive for PRE1 and negative for COM. For each 20B sub-area, the relationship between $PRE1_t$ and COM_{t+1} is positive with a steep slope for 20B1 and 20B2, which decreases towards 20B5 (Appendix 19C).

3.4.1.2. Relationships between $PRE2_t$ and $PRE1_{t+1}$

Positive but non-significant trends are observed between $PRE2_t$ and $PRE1_{t+1}$ in Area 20A (Figure 13A, Table 10). The trend is clearer for Group II. For the same abundance of PRE2, there are more $PRE1_{t+1}$ for Group II sub-areas than for Group I sub-areas (Figure 13A). The trends per sub-area (Appendix 20A) and the trends per year (Appendix 20B) vary considerably (positive to negative). There is a significant positive relationship (Table 10) between $PRE2_t$ and $PRE1_{t+1}$ for Area 20B (Figure 13B). Groups III and IV can be observed which are characterized respectively by low and strong values of $PRE2_t$ and $PRE1_{t+1}$. In addition, the relationship between $PRE2_t$ and $PRE1_{t+1}$ also tends to be positive between years and for each sub-area (Appendix 20C and D).

3.4.1.3. Relationships between $PRE2_t$ and COM_{t+2}

There is no clear relationship between $PRE2_t$ and COM_{t+2} in Area 20A, even at the level of the two groups of sub-areas (Figure 14A), although positive but non-significant trends are visible (Table 10). This pattern is similar to that found between $PRE2_t$ and $PRE1_{t+1}$. The trends per sub-area and year (Appendix 21A and B) vary considerably (positive to

negative) and reveal no clear pattern. In Area 20B, the relationship between $PRE2_t$ and COM_{t+2} is negative and significant (Figure 14B, Table 10, Appendix 20D). Group III is characterized by low values of $PRE2_t$ and Group IV by higher values (Figure 14B). Just like the relationship between $PRE1_t$ and COM_{t+1}, there is a spatial gradient of abundance going from 20B1 to 20B5, which is positive for $PRE2_t$ and negative for COM_{t+1}. The trends per sub-area (Appendix 21C) vary considerably (positive to negative).

Table 10. Results of linear regressions calculated between the different categories (classes) of lobster for time intervals of 1 or 2 years. The results are based on estimated mean annual CPUEs by sub-area.

Class	Sub-areas	Slope	Intercept	R^2	F	p
PRE1 (class 4)-COM (classes 5-6)	20A	0.3002	0.0696	0.61	38.01	< 0.0001
	20B	-0.1478	0.3538	0.11	2.31	0.1460
PRE1 (class 4)-PRE2 (classe 3)	20A-I	0.5651	0.0278	0.20	2.20	0.1718
	20A-II	0.4970	0.6366	0.08	1.17	0.2990
	20B	1.2310	0.0484	0.68	33.31	< 0.0001
PRE2 (class 3)-COM (classes 5-6)	20A-I	0.0824	0.1115	0.06	0.39	0.5556
	20A-II	0.3050	0.2215	0.19	1.86	0.2095
	20B	-0.2575	0.3723	0.12	4.46	0.0422

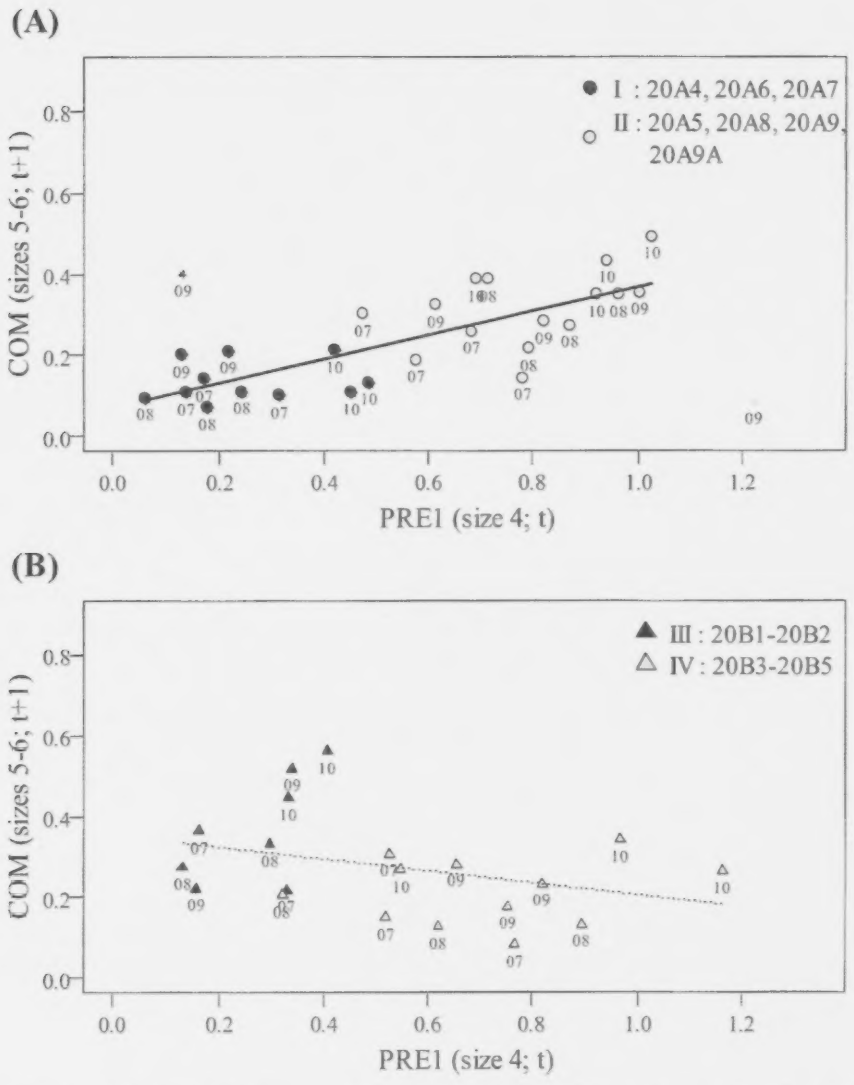


Figure 12. Relationships between $PRE1_t$ (size 4) and COM_{t+1} (sizes 5-6). The dots are annual means by sub-area. The numbers under each dot represent the year time "t". Areas 20A and 20B are respectively shown in (A) and (B). The lines represent the regression lines described in Table 10 (dotted: $p \geq 0.05$; full: $p < 0.05$). Extreme values are identified by "*" and were not considered in the analysis.

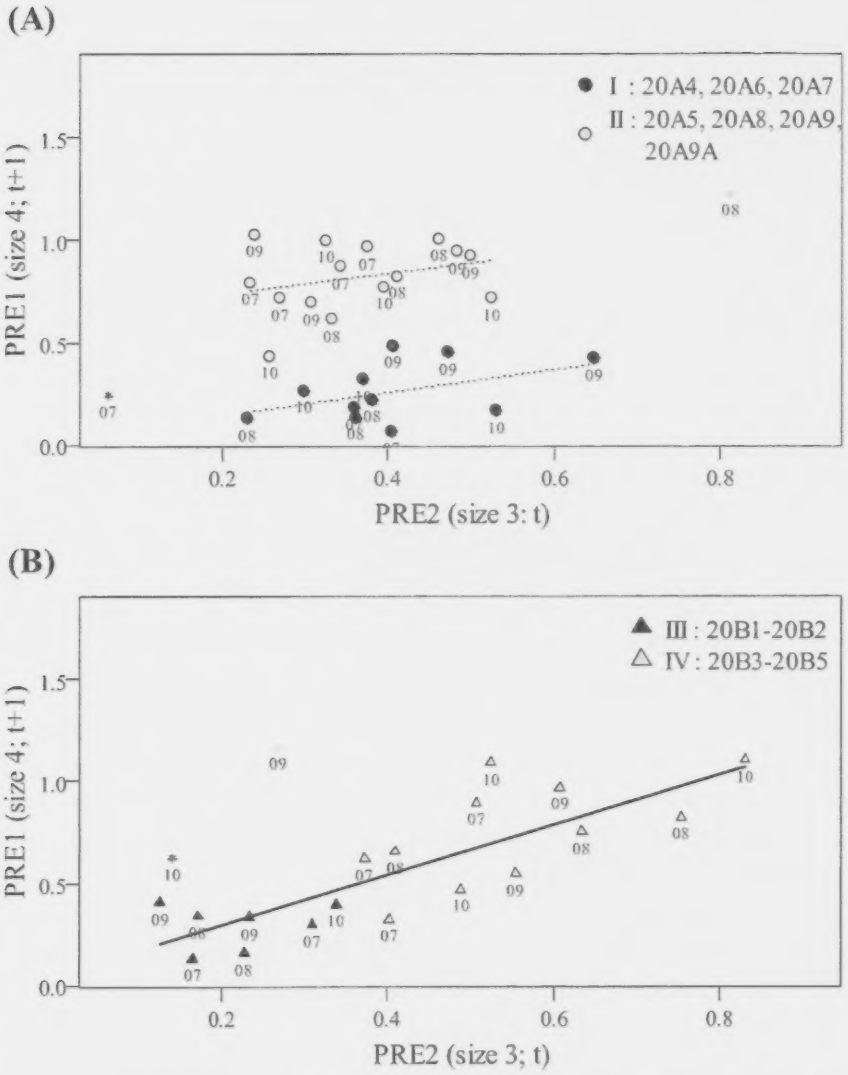


Figure 13. Relationships between $PRE2_t$ (size 3) and $PRE1_{t+1}$ (size 4). The dots are annual means by sub-area. The numbers under each dot represent the year time "t". Areas 20A and 20B are respectively shown in (A) and (B). The lines represent the regression lines described in Table 10 (dotted: $p \geq 0.05$; full: $p < 0.05$). Extreme values are identified by "*" and were not considered in the analysis.

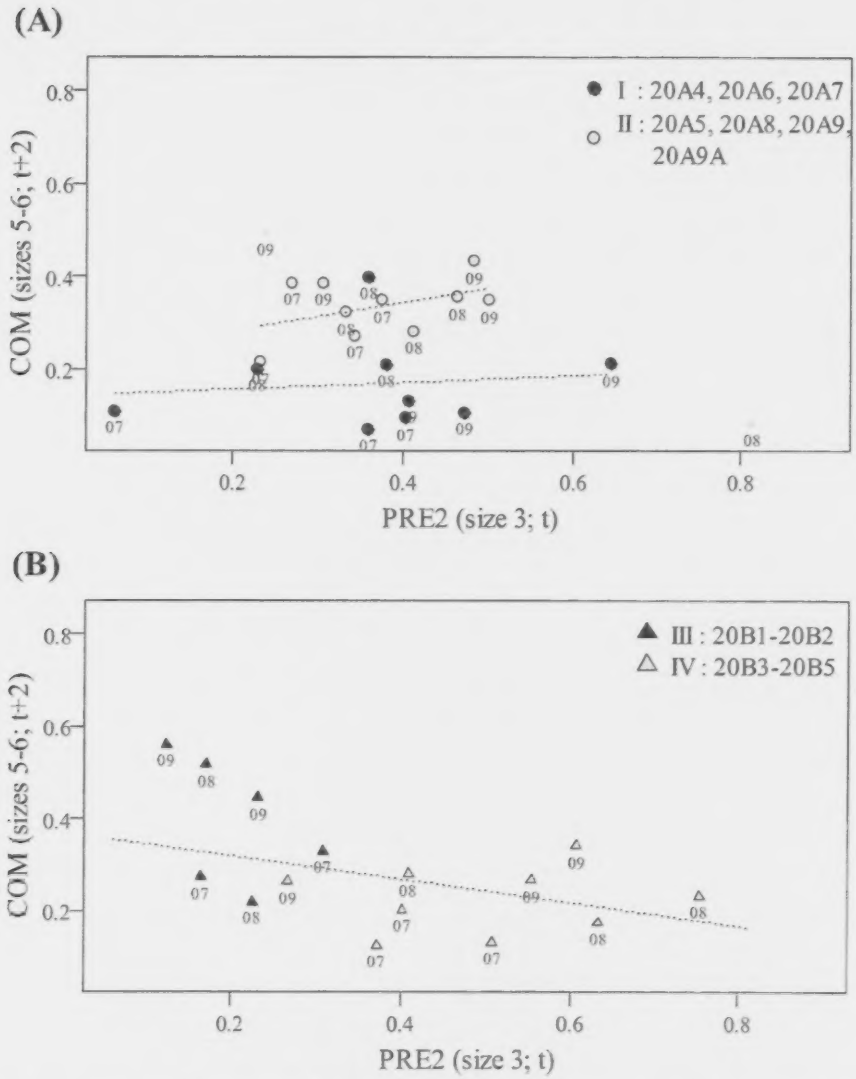


Figure 14. Relationships between $PRE2_t$ (size 3) and COM_{t-2} (sizes 5-6). The dots are annual means by sub-area. The numbers under each dot represent the year time "t". Areas 20A and 20B are respectively shown in (A) and (B). The lines represent the regression lines described in Table 10 (dotted: $p \geq 0.05$; full: $p < 0.05$). Extreme values are identified by "*" and were not considered in the analysis.

3.4.2. Forecasts – Areas 20A and 20B

Relationships between size classes $PRE1_t$-COM_{t+1} and $PRE2_t$-$PRE1_{t+1}$ are positive for both areas (Figures 15 and 16), but significant only for Area 20B (Table 11). Between $PRE2_t$ and COM_{t+2}, relationships are non-significant and the trends are difficult to determine (Figure 17).

Table 11. Results of linear regressions calculated between the different categories of lobster for time intervals of 1 or 2 years. The results are based on estimated mean annual CPUEs by area.

Class	Area	Slope	Intercept	R^2	F	p
PRE1 (class 4)-COM (classes 5-6)	20A	0.4333	-0.0072	0.87	13.29	0.0676
	20B	0.7158	-0.1027	0.99	657.90	0.0015
PRE1 (class 4)-PRE2 (class 3)	20A	1.3750	-0.0074	0.41	1.40	0.3587
	20B	1.4743	-0.1240	0.99	171.50	0.0058
PRE2 (class 3)-COM (classes 5-6)	20A	0.3178	0.3411	0.47	0.89	0.5182
	20B	-0.1194	0.5889	< 0.01	< 0.01	0.9569

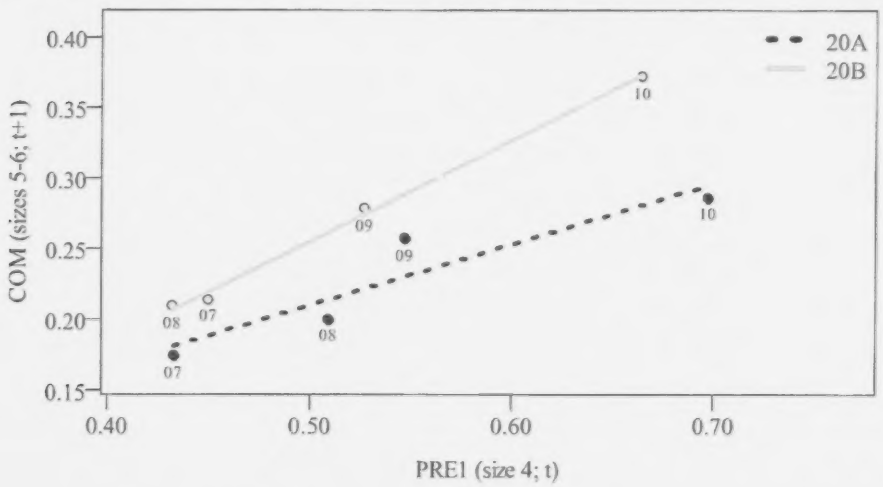


Figure 15. Relationships between $PRE1_t$ (size 4) and COM_{t+1} (sizes 5-6) for each area (20A and 20B). The dots are annual means by area. The numbers under each dot represent the year time "t". The lines represent the regression lines described in Table 11 (dotted: $p \geq 0.05$; full: $p < 0.05$).

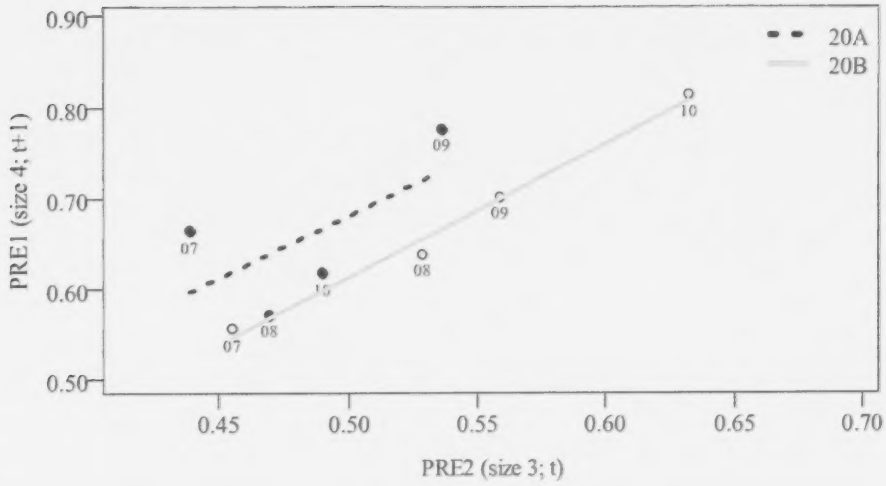


Figure 16. Relationships between $PRE2_t$ (size 3) and $PRE1_{t+1}$ (size 4) for each area (20A and 20B). The dots are annual means by area. The numbers under each dot represent the year time "t". The lines represent the regression lines described in Table 11 (dotted: $p \geq 0.05$; full: $p < 0.05$).

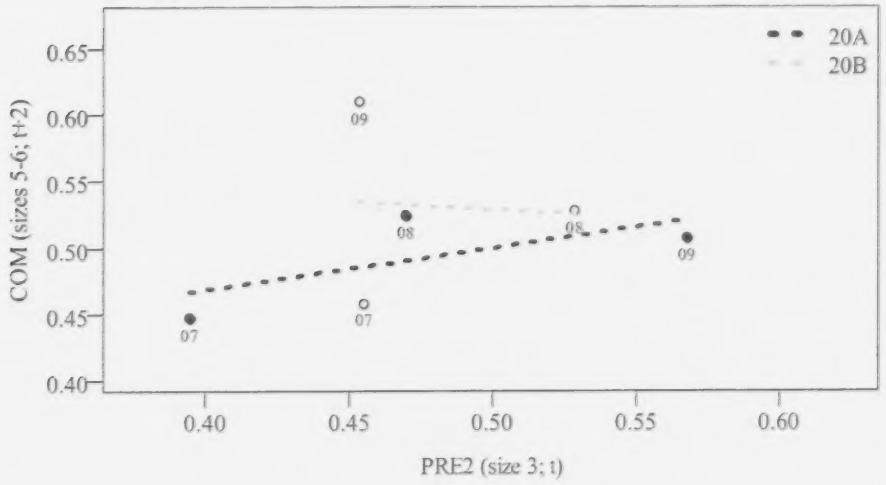


Figure 17. Relationships between $PRE2_t$ (size 3) and COM_{t-2} (sizes 5-6) for each area (20A and 20B). The dots are annual means by area. The numbers under each dot represent the year time "t". The lines represent the regression lines described in Table 11 (dotted: $p \geq 0.05$; full: $p < 0.05$).

4.0 DISCUSSION

This project's first objective was to describe the spatio-temporal distribution of the different categories of lobster using an abundance index (CPUE) from an experimental fishery. The second objective was to determine whether the abundance of pre-recruits could be used to predict the abundance of recruits to the fishery one or two years in advance. A significant feature of this project was that the sampling plan and data collection was carried out by the fishers themselves. Fishers worked daily throughout the season with commercial fishing gear, some of which were modified to retain small lobsters. This approach was adopted at the request of the fishers themselves who wanted to get involved in collecting data on their stocks. The project was designed based on what was already being done elsewhere in the Gulf of St. Lawrence and on the Atlantic coast, in particular in New Brunswick and Nova Scotia (Comeau et al. 2008 and Tremblay et al. 2011, 2012), which seemed appropriate for the Gaspé Peninsula. Sampling of pre-recruit lobsters requires the use of gear other than the traps used by fishers since traps are very selective and retain few lobsters of sub-commercial size because of regulatory escape vents (Gauthier and Hazel 1986). In recruitment studies conducted in the Magdalen Islands, a *Nephrops* bottom trawl with doors is used to catch small lobsters (Gendron and Savard 2012). The trawl is used on sandy bottoms around rocky reefs. However, on the Gaspé Peninsula, there are no such stretches of sandy bottoms so the use of this trawl is not possible. Tests were conducted in 2004 in sub-areas 20A6 and 20A10 but were unsuccessful (L. Gendron, unpublished data). This is why the use of lobster traps with blocked escape vents was preferred.

4.1 Abundance index calculation (CPUE)

The involvement of fishers provided considerably greater spatial and temporal coverage than that obtained in DFO's regular sampling program. DFO's lobster sampling program in LFA 20 on the Gaspé Peninsula has been conducted annually since 1986 at three sites (20A2, 20A8-A9 and 20B5-B6, see Figure 1). For each year and each site, six samples are collected (2 boats per site × 3 fishing trips per boat; a sample = measurement of all lobsters caught in one day or fishing trip) (Gendron and Savard 2012). Comeau et al. (2009) showed that greater spatial and temporal coverage could be more useful than punctual sampling conducted only two or three times in a season because it reduces the uncertainty of seasonal CPUE estimates. Furthermore, because of better spatial coverage,

it was possible to infer the results for a larger area. However, they showed that the calculation accuracy of the daily CPUE was generally lower because of the smaller number of traps used, compared for example to DFO's sampling program, where all traps hauled during a fishing day are sampled (n = 235). In this study, the use of only two standard traps and two modified traps per fishing day and per fisher had an impact on the accuracy of the abundance index, which was even more marked when CPUEs were low. When lobster abundance is low, catch probability is low and may even be lower than what the sampling plan can detect. The number of traps used in our study was probably insufficient to obtain a high accuracy for mean CPUE that were below or equal to 0.5 lobsters/trap. To improve accuracy, it would perhaps be necessary to consider increasing (doubling) the number of modified and/or regular traps that are deployed daily. This would increase lobster catchability, even with low abundance.

Calculating the abundance of a species using baited fishing gear always raises the issue of catchability for the target species. Lobster catchability is related to behaviour that can be affected by water temperature, currents, type of bait (see review by Miller, 1990) as well as the species' biology, namely sex , size and moult stage or reproductive condition. It has been known for a very long time that catchability increases with increasing water temperature (McLeese and Wilder 1958), which may have a direct impact on CPUE. In the lobster fishery on the Gaspé Peninsula, high CPUEs are observed at the beginning of the season when spring is early and the opposite when spring is late. The seasonal patterns of CPUEs are often affected by the temperature at the beginning of the fishing season, regardless of lobster abundance. Because the collection of data was done over the entire fishing season, the mean annual CPUEs calculated probably better reflect lobster abundance and therefore are comparable from one year to another.

Lobster catchability is also affected by competitive intra and inter-specific interactions that can occur upon entry to the trap (Miller 1990, Richards et al. 1983). It has been previously observed that the presence of large lobsters in a trap inhibits smaller lobsters from entering (Miller 1989, Richards et al. 1983). Although these interactions occur primarily at high densities, Smolowitz (1978) mentions that sometimes just one or two lobsters in a trap can influence whether others will be caught. In our study, we observed a slight upward trend in the amount of PRE1 and PRE2 according to time (Appendices 2 and 3). This increase is associated with the decrease of COM (Appendix 1), but it is not possible to establish a causal link between the two trends. In a similar study conducted in Nova Scotia, an increase in CPUE for pre-recruits was sometimes observed at the same time as a decrease in CPUE for commercial-size lobsters. No causal link was established

between these two events and the increase in pre-recruit CPUE was instead attributed to an increase in catchability because of the warmer temperature towards the end of the fishing season (Tremblay et al. 2011). The collection of data over all or a large portion of the fishing season rather than over a short period of time, which varies from one year to another, provides a calculation of annual means that further reflect lobster abundance and can be compared from one year to another. However, the idea of using smaller entrance rings such as in Nova Scotia (Tremblay et al. 2011) to mitigate the potential effect of large lobsters in the traps on the capture of pre-recruits could be considered in the future.

Another source of variation that could affect the abundance index calculated for a sub-area is the fisher. It is worth mentioning that it was not always the same fishers who participated in the project over the years. Participant turnover is typical for this type of project. After participating for a few years, most fishers feel they have contributed enough and want to give way to others. Sixteen fishers consistently participated in the project, which represents a proportion ranging from 59 to 72% of all participants depending on the year. Fishers who did not participate in the project from the beginning were not excluded from the analysis, as that would have excluded several sub-areas from the analyses. The fisher effect was not considered in the analyses. However, there may be differences between fishers and changing the fisher in a sub-area in a given year could potentially present noise and mask interannual and inter-area differences. In general, the differences that may exist between fishers from a sub-area are not technological in nature since the fishing effort is well controlled and fishers have relatively similar fishing gear and methods. Differences that may exist between fishers are rather related to the type of sea bottom harvested by each fisher. Despite the fact that this is a competitive fishery, fishers have traditionally been somewhat territorial. Geographic coordinates, although partial, show this spatial segregation by fishers within a sub-area. There could be differences between fishers were they restricted to harvesting sea bottoms with different yields. That being said, it is reasonable to suggest that the inter-fisher variance within a sub-area, associated with the geographic location of samples, may be an approximation of the true variance of lobster abundance in this sub-area.

Though many factors may have influenced catch rates, it is assumed that the observed CPUE variations represent an indicator of changes in lobster abundance, and they are interpreted as such in the following sections. We consider that the data clustering and processing methods that have been used have helped control some of the variability and eliminate some of the noise in the data. The calculation of a mean CPUE to equally represent two different fishing periods and reduce null-value impacts by compiling data

on a weekly basis helped structure the data to facilitate interannual and inter-area comparisons. In the future, further analysis of the data could be attempted. Different types of models (GLM, GAM, GAMM) could be applied to the data to try to reduce the proportion of unexplained variation and better reflect interannual differences between sub-areas in terms of lobster abundance by introducing explanatory quantitative variables (e.g., temperature).

4.2 Spatio-temporal variations in abundance (CPUE)

The analysis of the spatial and temporal variability in CPUEs was first done by ANOVA. Because of the considerable variability in the data, only large differences in CPUEs stood out statistically in the multiple comparison analyses However, further review of the distribution of abundance values compared with the 25th, 50th (median) and 75th distribution percentiles of all values revealed certain patterns and trends.

During the study period, from 2007 to 2011, there was an overall upward trend in CPUEs. Between 2009 and 2010 in particular, there was a relatively substantial increase in the abundance of PRE1, COM and BF. In 2011, the mean CPUE was the highest for all categories of lobster. By comparison, lobster landings recorded on the Gaspé Peninsula for the same period also showed an increase (DFO 2012).

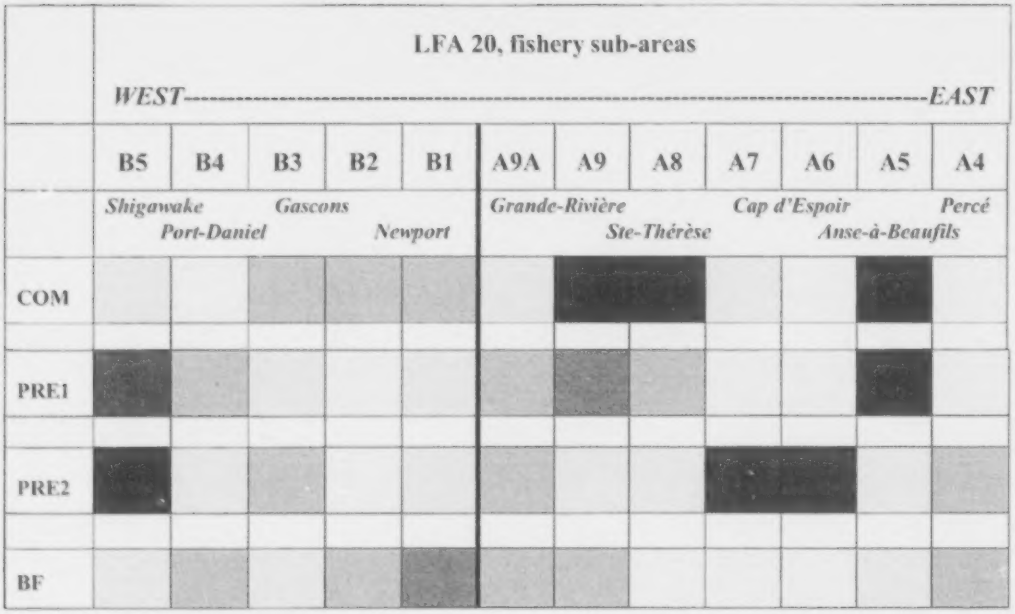
CPUE comparison between the different sub-areas during the five-year study showed that spatial heterogeneity was relatively significant in terms of lobster abundance throughout the area for each category of lobster. Correlation analysis showed some consistency from one year to the next in abundance differences between sub-areas for each category of lobster. This result indicates that there is in fact a spatial structure in the distribution of lobster along the Gaspé Peninsula, with areas of high abundance and others with relatively low abundance. These differences may be related to habitat characteristics, which could be more favourable in some areas than others for certain categories of lobster. Thus, we can see areas where commercial-size lobsters (COM) are always more abundant, such as from Ste-Thérèse to Gascons (20A8 to 20B3) and a small area in Anse-à-Beaufils (20A5). There are also areas where abundance is lower, such as Port-Daniel and Shigawake (20B4 and 20B5) on the one hand, and the areas east and west of Anse-à-Beaufils (20A4 and 20A6) on the other. The heterogeneity in the abundance of lobster along the Gaspé Peninsula has been observed in the past from landings and different sampling campaigns (Gendron and Savard, 2003, 2008 and 2012). The Ste-Thérèse and Grande-Rivière (20A8 and 20A9) area has always been regarded as an area of relatively

high abundance, whereas areas farthest upstream from Area 20B have often shown relatively lower abundance, which is similar to the results of this study. The introduction of a mandatory daily logbook for all Gaspé Peninsula fishers (174 fishers in Area 20) in 2012 will provide a much clearer idea of the spatial patterns of lobster abundance in the Gaspé and how they evolve over time. It remains difficult and uncertain to define the lobster distribution patterns on the Gaspé Peninsula from data collected on small spatial or temporal scales or in the absence of essential data such as fishing effort.

Stronger contrasts were observed between sub-areas for pre-recruits 70 to 82 mm (PRE1). Ste-Thérèse and Grande-Rivière (20A8 to 20A9), a small area of Anse-à-Beaufils (20A5), as well as Port-Daniel and Shigawake (20B4 and 20B5) are areas of high abundance. In contrast, few pre-recruits were observed during the five-year study in the areas east and west of Anse-à-Beaufils (20A4 and 20A6), Cap d'Espoir (20A7) and from Newport to Gascons (20B1 to 20B3). Pre-recruits < 70 mm (PRE2) have always been relatively abundant in areas east and west of Anse-à-Beaufils (20A4 and 20A6) and Cap d'Espoir (20A7) and in Shigawake (20B5). However, very few small lobsters were caught in Newport-west (20B2). This is the first time that lobster pre-recruit distribution has been described in these areas. As mentioned above, there is uncertainty about the patterns described because of the spatial scale of observation. However, they can at least serve as a basis to develop more specific projects that will help validate and refine these distribution patterns.

Berried females were very abundant in the Newport-west area (20B1) during the five-year study. They were relatively less abundant in the area from Anse-à-Beaufils to Grande-Rivière (20A6 to 20A8). An at-sea sampling campaign conducted on the Gaspé Peninsula in 2004, covering almost all sub-areas, also provided information on the spatial distribution of berried females, in particular larger individuals (Gendron and Savard 2008). This study also showed that the abundance distribution was not homogeneous throughout the area, with patterns that could be seen as similar to those described above.

The following diagram summarizes the information on the abundance of the different categories of lobster observed during the five-year study. Areas are classified according to an increasing gradient of abundance going from lightest to darkest. Areas of highest abundance (black) correspond to those with total CPUE values above the 75th percentile. The other categories, dark gray, medium gray and light gray, correspond to areas with CPUE values that are between the median and the 75th percentile, between the 25th percentile and the median, and below the 25th percentile, respectively (see Section 3.2).



4.3 Recruitment indicator

The second objective of the study was to evaluate the pre-recruit abundance index potential to predict the abundance of commercial-size lobsters (COM) one or two years in advance. To reduce noise in the data and facilitate the analyses, the study of interannual relationships was conducted on males only. The study of interannual relationships among females is more complex and must take into account the fact that a female pre-recruit could spawn in a given year, thus delaying by one year its entry into the fishery as a recruit. Analyses were restricted to size classes 3, 4 and 5 to 6, each corresponding to successive moult classes (Table 2).

Our data indicate that for 20A, the abundance of commercial-size lobsters (new recruits, COM, classes 5 to 6) in a given year can be predicted by the abundance of pre-recruits one moult prior to commercial size (PRE1, class 4) measured the previous year. Regression calculated between the two groups is positive and significant. The prediction appears to be feasible for the entire Area 20A and for the two sub-area groups identified above (Section 3.4): one is characterized by low abundance and the other by high abundance in terms of both pre-recruits and commercial-size lobsters.

The situation seemed slightly more complex in Area 20B where the relationship between $PRE1_t$ and COM_{t-1} was negative and non-significant. However, this negative relationship

appears to result from a reverse spatial gradient in the abundance of pre-recruit and commercial-size lobsters between Gascons (20B1) and Shigawake (20B5). The gradient is negative for commercial-size lobsters and positive for pre-recruits (Appendix 19C and D). However, within each sub-area in Area 20B, the trend between $PRE1_t$ and COM_{t+1} is positive with an increasing slope from 20B5 to 20B1. At the extreme eastern limit of 20B (20B1), the abundance of commercial-size lobsters is relatively high and appears to vary independently of $PRE1_t$, which almost always remain low. In the western part of 20B (20B5), the relatively high abundance and variations of $PRE1_t$ do not appear to really affect the abundance of COM_{t+1}, which remains relatively consistent and low (Appendix 19D). Presumably, in light of these patterns in this area of the Gaspé Peninsula, there may be areas that are more favourable to pre-recruits and others that are more favourable to commercial-size lobsters. However, the reasons for this spatial segregation are not yet known. The high abundance of COM_{t+1} in an area where the abundance of $PRE1_t$ is low, as well as the low abundance of COM_{t+1} despite a relatively high abundance of $PRE1_t$, could be the result of the displacement of pre-recruit lobsters from 20B5 to 20B1. In this context, it would be reasonable to expect that an increase in the abundance of PRE1 upstream from Chaleur Bay (20B5 and 20B4) could contribute to recruitment to the fishery in areas located further downstream from Chaleur Bay (20B2 and 20B1). This hypothesis is considered because it is consistent with the results of a lobster mark-recapture project corresponding to the PRE1 and COM categories in this study, conducted in these areas in 2002 and 2003 (Hardy 2007). The results of that project indicated that lobsters from Areas 20B5 and 20B6 made relatively significant movements (4.6 ± 0.3 km on average) parallel to the coast and mostly in the north-east direction. The distance covered in this specific direction was also greater (around 6 km) than for all directions, a distance sometimes more extensive than the width of a fishing sub-area (Hardy 2007). In this regard, it is interesting to observe that in 20A, where the relationship between the abundance of PRE1 and COM shows a positive and constant slope, lobster movements recorded in the same project were rather marginal (1.1 ± 0.1 km) and occurred along the coast without any predominant direction.

For the time being, because of a short data series (3 values), it is still too early to determine whether recruitment to the fishery can be predicted two years in advance using the pre-recruit 2 group (PRE2, class 3). The relationships obtained between COM_{t+2} and $PRE2_t$ vary widely depending on the sub-areas. In 20B, the relationship is opposite, such as that between COM_{t+1} and $PRE1_t$, and appears to be related to the spatial gradient described above. The relationship between $PRE2_t$ and $PRE1_{t+1}$ is also very high, which

suggests that PRE1 and PRE2 lobster groups could probably be found on the same grounds. In Area 20A, the relationship between COM_{t-2} and $PRE2_t$ is positive but non-significant. A positive trend between $PRE2_t$ and $PRE1_{t+1}$ can also be observed but it is non-significant. In addition, for a given $PRE2_t$ value, different $PRE1_{t+1}$ values can be observed. These values are higher for 20A5, 20A8 and 20A9-A9A (Group II) than for 20A4, 20A6 and 20A7 (Group I). It can be assumed that Group I sub-areas provide a favourable habitat for small lobsters (PRE2) but when they reach a larger size, they move elsewhere. However, there has not been any marking program in this area that can confirm this. It is interesting to note that the three Group I sub-areas are among those that have the highest abundances of PRE2. This could be an indication of the presence of nearby nursery grounds, i.e., sites favourable for the survival and growth of lobsters in the early years of their benthic life. However, this needs to be confirmed.

These observations show the importance of understanding the spatial dynamics and connectivity between different lobster size groups in the development of forecasting tools. Relationships will be more difficult to establish if there are certain movements that cause spatial segregation between groups. When movements occur without any predominant direction and over short distances, i.e., within the spatial unit considered, it is highly likely that a positive relationship between lobster categories may appear, thus facilitating the development of forecasts. However, in areas where movements are directional and greater distances are covered, i.e., greater than the study's spatial unit, relationships between lobster categories will be more difficult to establish. This study focused on the sub-area, but in light of the spatial distribution patterns that seem to emerge, it is clear that for the development of projected relationships, the optimal spatial unit remains to be defined. There is still much work to be done to understand this dynamic and this study should be considered as a first step in establishing certain bases and developing possible hypotheses.

We also calculated mean annual CPUEs throughout the areas (20A and 20B), avoiding uncertainties regarding the spatial connectivity between different size classes throughout the sub-areas. This can certainly help make forecasts for the entire area, but does not specify in which parts of the area changes can be observed. Thus, the mean abundance of COM (recruits of the year) in a given year can reasonably be predicted by that of PRE1 one year in advance. However, a longer temporal series is necessary to better reflect the relationship between the different size classes and attempt to predict in the longer term (two years) the trend in the abundance of commercial-size lobsters.

5.0 CONCLUSION

Data collected between 2007 and 2011 by Gaspé Peninsula fishers have helped improve our knowledge of the spatial distribution of lobsters and lay the groundwork for the development of a forecasting tool of recruitment to the fishery, using pre-recruit abundance calculations. Although multiple sources of variation may have affected the accuracy of the abundance index (CPUE), we believe that despite the noise, it is reasonable to assume that the signals detected in the CPUEs of different lobster categories can be interpreted as changes in the abundance of lobster. Only significant differences in CPUE stood out statistically, but the study of trends and the relative changes in CPUE allowed us to highlight certain spatial-temporal patterns. Over the years, there has been an increase in the abundance of lobster for most sub-areas. The study also revealed a spatial structure in the distribution of each lobster category. Observations suggest that some sub-areas, possibly because of type of habitat or productivity level, are better suited for pre-recruits while others support more commercial-size lobsters. Taken together, these observations emphasized the importance of considering the spatial connectivity between categories of lobster in order to develop tools for predicting recruitment to the fishery from pre-recruit abundance calculations. The spatial scale of forecasts must be adjusted to the spatial scale of movements between relevant lobster categories. However, a larger scale approach (area) helps make more general forecasts. A longer temporal series is essential to better understand interannual fluctuations in CPUE and better define the spatial patterns of distribution. To develop a recruitment index with a satisfactory predictive power, it is essential to increase the accuracy of abundance estimates by promoting greater participation in the project (number of fishers and number of traps) and reducing or quantifying the significance of different sources of variation that are likely to have an important impact on abundance estimates.

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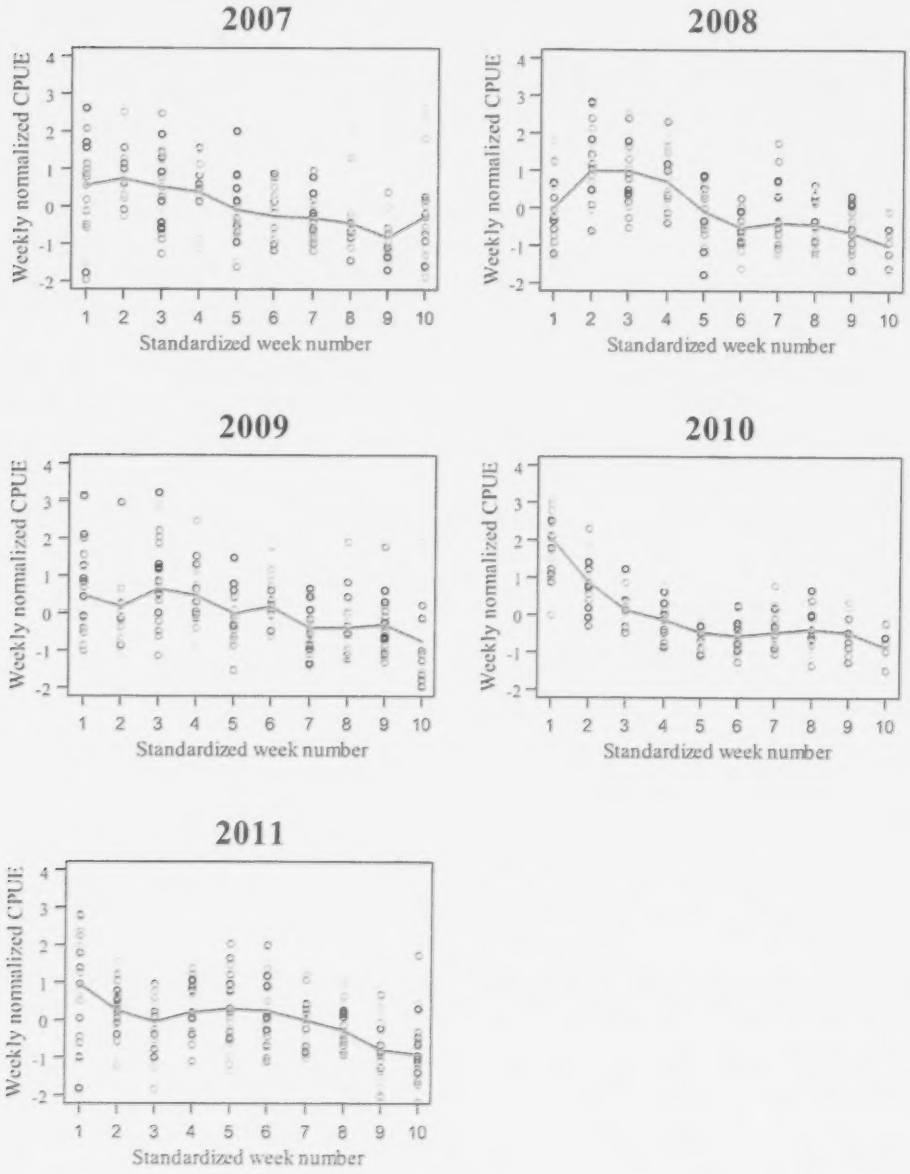
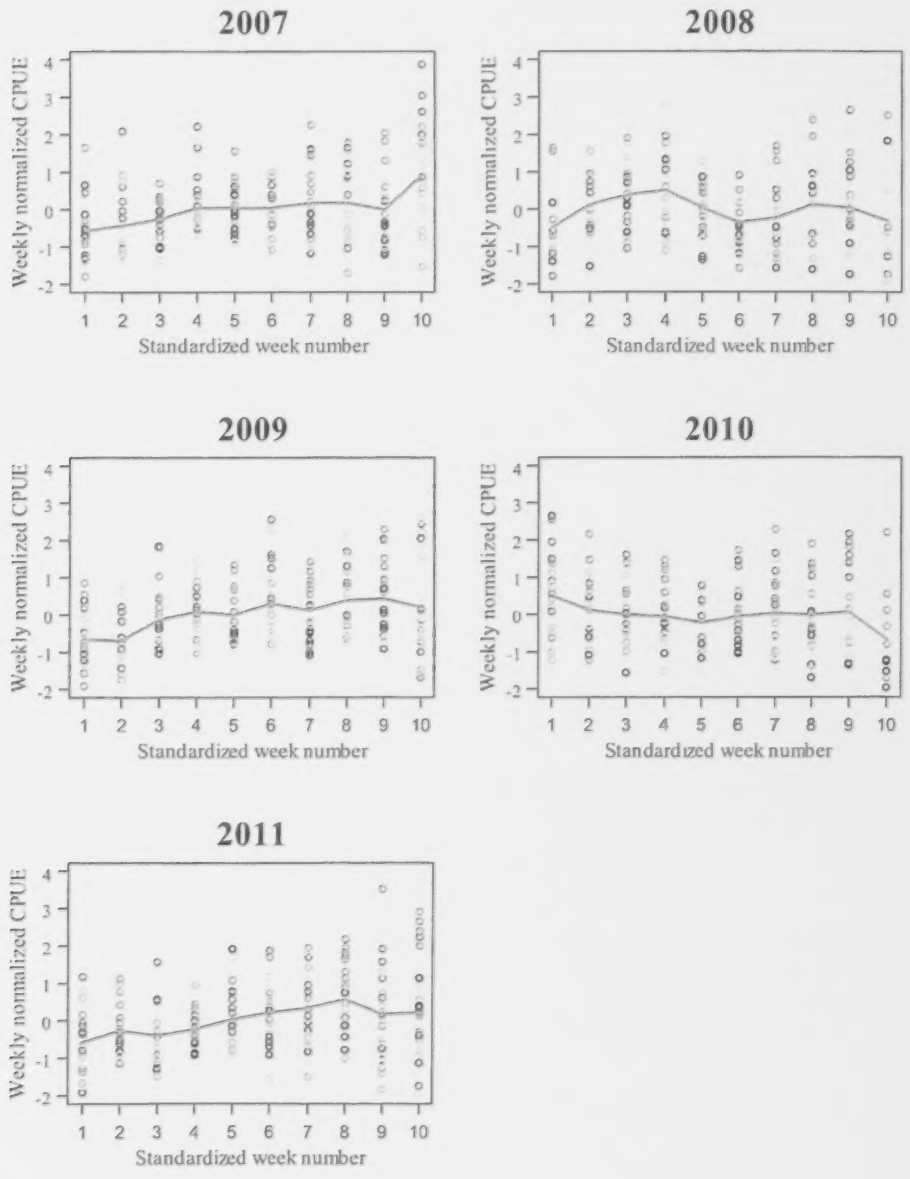
8.0 APPENDICES

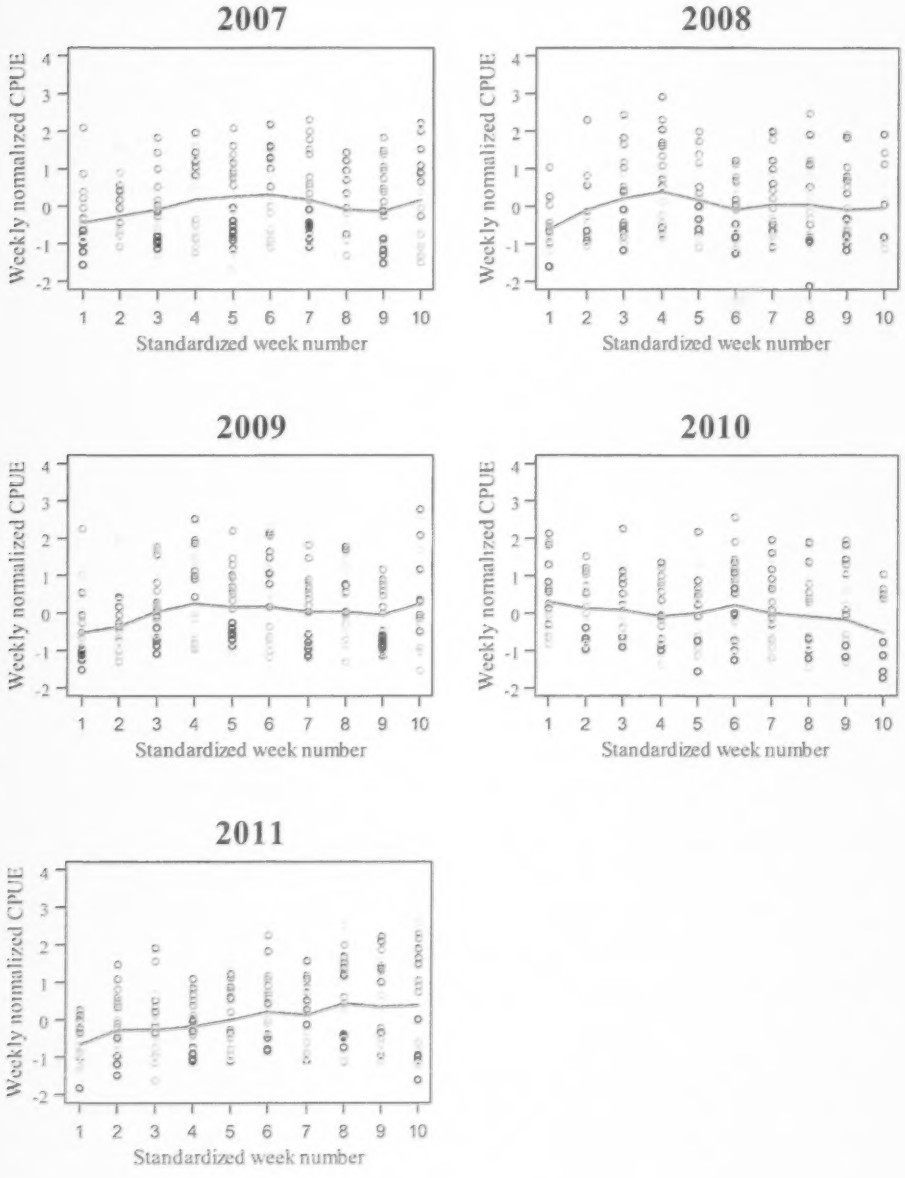
Appendix 1. Variation of weekly CPUEs of COM for each year. The data were normalized (centered and reduced) by sub-area and year.



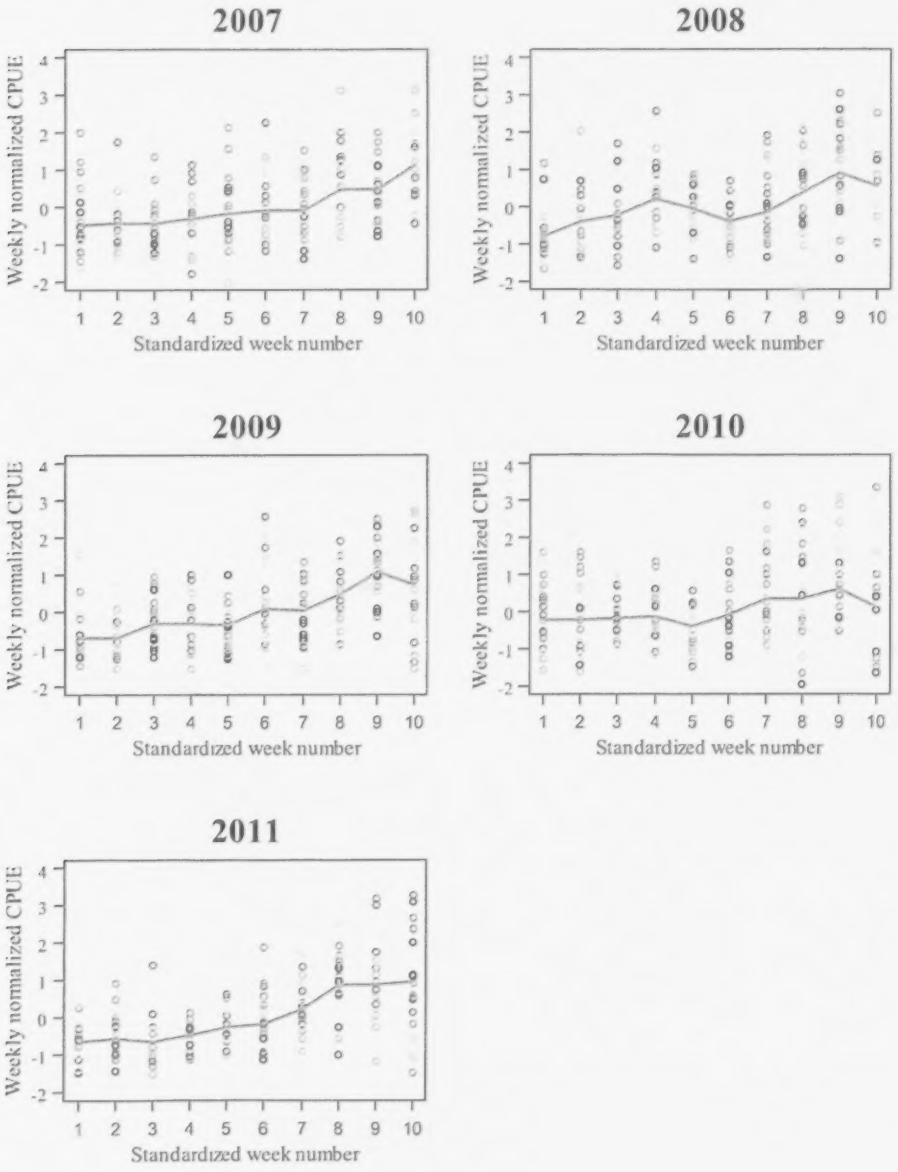
Appendix 2. Variation of weekly CPUEs of PRE1 for each year. The data were normalized (centered and reduced) by sub-area and year.



Appendix 3. Variation of weekly CPUEs of PRE2 for each year. The data were normalized (centered and reduced) by sub-area and year.



Appendix 4. Variation of weekly CPUEs of BF for each year. The data were normalized (centered and reduced) by sub-area and year.



Appendix 5. Mean annual CPUEs in number/trap (± standard error) for COM, PRE1, PRE2 and BF categories, estimated by sub-area for 2007 to 2011.

Category	Sub-Area	2007	2008	2009	2010	2011
COM	20A4	0.28 (±0.08)	0.21 (±0.07)	0.08 (±0.05)	0.28 (±0.09)	0.33 (±0.09)
	20A5	0.43 (±0.10)	0.62 (±0.13)	0.73 (±0.14)	0.78 (±0.14)	0.98 (±0.16)
	20A6	0.30 (±0.09)	0.50 (±0.12)	0.15 (±0.06)	0.42 (±0.10)	0.36 (±0.10)
	20A7	0.39 (±0.10)	0.34 (±0.10)	0.56 (±0.12)	1.13 (±0.18)	0.66 (±0.14)
	20A8	0.84 (±0.15)	0.63 (±0.15)	0.57 (±0.12)	0.93 (±0.16)	0.94 (±0.15)
	20A9A	0.53 (±0.12)	0.37 (±0.10)	0.92 (±0.15)	0.27 (±0.08)	0.64 (±0.13)
	20A9	0.51 (±0.11)	0.77 (±0.15)	1.18 (±0.17)	0.56 (±0.12)	0.96 (±0.16)
	20B1	0.65 (±0.13)	0.80 (±0.14)	0.55 (±0.12)	0.57 (±0.12)	0.78 (±0.14)
	20B2	0.36 (±0.09)	0.58 (±0.12)	0.61 (±0.12)	1.56 (±0.23)	0.97 (±0.16)
	20B3	0.61 (±0.12)	0.62 (±0.12)	0.40 (±0.10)	0.58 (±0.12)	0.62 (±0.12)
	20B4	0.34 (±0.09)	0.25 (±0.08)	0.31 (±0.09)	0.43 (±0.11)	0.61 (±0.12)
	20B5	0.38 (±0.10)	0.35 (±0.09)	0.17 (±0.07)	0.49 (±0.12)	0.77 (±0.14)
PRE1	20A4	0.82 (±0.16)	0.53 (±0.14)	0.56 (±0.14)	0.86 (±0.17)	0.70 (±0.15)
	20A5	1.31 (±0.18)	2.71 (±0.23)	2.37 (±0.21)	2.16 (±0.20)	2.82 (±0.22)
	20A6	0.62 (±0.15)	0.60 (±0.15)	0.54 (±0.14)	1.12 (±0.17)	0.54 (±0.14)
	20A7	0.70 (±0.15)	0.54 (±0.15)	0.68 (±0.15)	0.89 (±0.17)	1.32 (±0.19)
	20A8	1.47 (±0.18)	2.33 (±0.25)	1.85 (±0.19)	2.64 (±0.23)	1.92 (±0.20)
	20A9A	2.15 (±0.20)	2.31 (±0.22)	3.11 (±0.22)	2.17 (±0.20)	2.92 (±0.22)
	20A9	1.04 (±0.17)	1.69 (±0.20)	1.86 (±0.19)	1.87 (±0.19)	1.15 (±0.17)
	20B1	0.76 (±0.15)	0.69 (±0.15)	0.62 (±0.15)	1.13 (±0.17)	1.29 (±0.18)
	20B2	0.75 (±0.15)	0.74 (±0.15)	1.14 (±0.17)	0.70 (±0.17)	1.89 (±0.20)
	20B3	1.10 (±0.17)	0.76 (±0.15)	1.29 (±0.18)	1.33 (±0.18)	1.50 (±0.18)
	20B4	2.18 (±0.20)	2.09 (±0.21)	2.01 (±0.20)	3.20 (±0.24)	3.06 (±0.22)
	20B5	1.44 (±0.18)	2.00 (±0.20)	1.80 (±0.19)	2.49 (±0.22)	2.83 (±0.22)

Appendix 5 (continued)

Category	Sub-Area	2007	2008	2009	2010	2011
PRE2	20A4	1.26 (±0.16)	1.22 (±0.16)	1.85 (±0.19)	1.65 (±0.19)	1.34 (±0.17)
	20A5	0.81 (±0.14)	0.99 (±0.16)	1.24 (±0.16)	1.32 (±0.17)	0.92 (±0.15)
	20A6	1.57 (±0.18)	1.42 (±0.18)	1.98 (±0.19)	1.51 (±0.18)	2.29 (±0.20)
	20A7	1.51 (±0.18)	1.99 (±0.21)	2.28 (±0.20)	1.34 (±0.18)	2.13 (±0.21)
	20A8	0.63 (±0.13)	0.85 (±0.17)	1.15 (±0.16)	1.18 (±0.17)	0.98 (±0.15)
	20A9A	1.21 (±0.16)	2.51 (±0.23)	1.52 (±0.18)	0.89 (±0.14)	1.83 (±0.19)
	20A9	0.55 (±0.12)	1.21 (±0.17)	1.49 (±0.17)	1.01 (±0.15)	1.29 (±0.17)
	20B1	0.88 (±0.14)	1.30 (±0.17)	0.98 (±0.15)	1.14 (±0.16)	2.08 (±0.20)
	20B2	0.75 (±0.14)	0.77 (±0.14)	1.03 (±0.15)	0.22 (±0.11)	0.73 (±0.14)
	20B3	0.79 (±0.14)	1.34 (±0.17)	1.48 (±0.17)	1.08 (±0.16)	1.79 (±0.19)
	20B4	1.13 (±0.16)	1.85 (±0.20)	0 94 (±0.15)	1.47 (±0.18)	0.96 (±0.15)
	20B5	1.36 (±0.17)	2.13 (±0.20)	1.50 (±0.18)	2.79 (±0.23)	2.85 (±0.22)
BF	20A4	0.21 (±0.07)	0.27 (±0.08)	0.42 (±0.10)	0.87 (±0.14)	0.59 (±0.11)
	20A5	0.25 (±0.08)	0.46 (±0.11)	0.20 (±0.07)	0.26 (±0.08)	0.55 (±0.11)
	20A6	0.88 (±0.13)	0.14 (±0.06)	0.09 (±0.05)	0.18 (±0.07)	0.28 (±0.08)
	20A7	0.19 (±0.07)	0.09 (±0.05)	0.27 (±0.08)	0.01 (±0.03)	0.38 (±0.10)
	20A8	0.14 (±0.06)	0.19 (±0.08)	0.11 (±0.05)	0.33 (±0.09)	0.32 (±0.08)
	20A9A	0.39 (±0.09)	0.26 (±0.08)	0.25 (±0.08)	0.31 (±0.08)	0.72 (±0.12)
	20A9	0.11 (±0.05)	0.36 (±0.09)	0.45 (±0.10)	0.52 (±0.10)	0.45 (±0.10)
	20B1	0.78 (±0.13)	1.52 (±0.17)	1.09 (±0.15)	1.31 (±0.16)	1.61 (±0.18)
	20B2	0.10 (±0.05)	0.37 (±0.09)	0.49 (±0.10)	0.65 (±0.14)	0.32 (±0.08)
	20B3	0.07 (±0.05)	0.30 (±0.08)	0.23 (±0.07)	0.26 (±0.08)	0.92 (±0.14)
	20B4	0.19 (±0.07)	0.38 (±0.10)	0.20 (±0.07)	0.43 (±0.10)	0.33 (±0.09)
	20B5	0.20 (±0.07)	0.19 (±0.07)	0.10 (±0.05)	0.30 (±0.09)	0.28 (±0.08)

CPUE values for COM come from regular traps and values for PRE1, PRE2 and BF come from modified traps.

Appendix 6. Results ("p" values) of the analysis of multiple comparisons between years by sub-area for COM.

Year	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4	20B5
2007 - 2008	1	1	1	1	1	1	1	1	1	1	1	1
2007 - 2009	1	1	1	1	1	0.0984	1	1	1	1	1	1
2007 - 2010	1	1	1	0.01	1	1	1	1	<0.0001	1	1	1
2007 - 2011	1	0.3882	1	1	1	1	1	1	0.0506	1	1	1
2008 - 2009	1	1	0.5398	1	1	1	0.2694	1	1	1	1	1
2008 - 2010	1	1	1	0.0027	1	1	1	1	0.0058	1	1	1
2008 - 2011	1	1	1	1	1	1	1	1	1	1	1	1
2009 - 2010	1	1	1	0.8807	1	0.3415	0.0051	1	0.0135	1	1	1
2009 - 2011	0.7206	1	1	1	1	1	1	1	1	1	1	0.0009
2010 - 2011	1	1	1	1	1	1	1	1	1	1	1	1

Appendix 7. Results ("p" values) of the analysis of multiple comparisons between sub-areas by year for COM.

2007	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	1										
20A6	1	1									
20A7	1	1	1								
20A8	0.0416	1	0.0776	1							
20A9	1	1	1	1	1						
20A9A	1	1	1	1	1	1					
20B1	1	1	1	1	1	1	1				
20B2	1	1	1	1	0.5563	1	1	1			
20B3	1	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	0.3715	1	1	1	1	1	
20B5	1	1	1	1	0.9212	1	1	1	1	1	1

2008	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.369										
20A6	1	1									
20A7	1	1	1								
20A8	0.6157	1	1	1							
20A9	0.0139	1	1	1	1						
20A9A	1	1	1	1	1	1					
20B1	0.004	1	1	0.7906	1	1	1				
20B2	0.6616	1	1	1	1	1	1	1			
20B3	0.2959	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	1	0.1273	1	0.0483	1	1	
20B5	1	1	1	1	1	1	1	0.8556	1	1	1

Appendix 7. (continued)

2009	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	< 0.0001										
20A6	1	0.0012									
20A7	0.0007	1	0.1023								
20A8	0.0004	1	0.0715	1							
20A9	< 0.0001	1	< 0.0001	0.3403	0.4693						
20A9A	< 0.0001	1	< 0.0001	1	1	1					
20B1	0.0008	1	0.1187	1	1	0.2964	1				
20B2	0.0001	1	0.0258	1	1	1	1	1			
20B3	0.0768	1	1	1	1	0.0045	0.4837	1	1		
20B4	1	1	1	1	1	0.0001	0.0237	1	1	1	
20B5	1	0.003	1	0.2134	0.1497	< 0.0001	< 0.0001	0.2465	0.0567	1	1

2010	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.2494										
20A6	1	1									
20A7	0.0003	1	0.032								
20A8	0.0218	1	0.9877	1							
20A9	1	1	1	0.8832	1						
20A9A	1	0.1139	1	0.0001	0.0085	1					
20B1	1	1	1	1	1	1	1				
20B2	< 0.0001	0.4288	< 0.0001	1	1	0.0032	< 0.0001	0.0044			
20B3	1	1	1	1	1	1	1	1	0.0059		
20B4	1	1	1	0.0664	1	1	1	1	0.0001	1	
20B5	1	1	1	0.3165	1	1	1	1	0.0009	1.0000	1

Appendix 7. (continued)

2011	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.0153										
20A6	1	0.0472									
20A7	1	1	1								
20A8	0.0343	1	0.0995	1							
20A9	0.0247	1	0.0734	1	1						
20A9A	1	1	1	1	1	1					
20B1	0.7071	1	1	1	1	1	1				
20B2	0.0186	1	0.0563	1	1	1	1	1			
20B3	1	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	1	1	1	1	1	1	
20B5	0.838	1	1	1	1	1	1	1	1	1	1

Appendix 8. Results ("p" values) of the analysis of multiple comparisons between years by sub-area for PRE1.

Year	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4	20B5
2007 - 2008	1	0.0001	1	1	0.7677	1	1	1	1	1	1	1
2007 - 2009	1	0.0138	1	1	1	0.1958	0.2343	1	1	1	1	1
2007 - 2010	1	0.2194	1	1	0.0083	0.1673	1	1	1	1	0.1901	0.0386
2007 - 2011	1	<0.0001	1	1	1	1	1	1	0.0004	1	0.5421	0.0001
2008 - 2009	1	1	1	1	1	1	1	1	1	1	1	1
2008 - 2010	1	1	1	1	1	1	1	1	1	1	0.0937	1
2008 - 2011	1	1	1	0.1379	1	1	1	1	0.0003	0.2543	0.2722	0.8187
2009 - 2010	1	1	1	1	1	1	0.2960	1	1	1	0.0212	1
2009 - 2011	1	1	1	0.9475	1	0.9478	1	0.4024	0.5623	1	0.0712	0.0618
2010 - 2011	1	1	1	1	1	0.8316	1	1	0.0007	1	1	1

Appendix 9. Results ("p" values) of the analysis of multiple comparisons between sub-areas by year for PRE1.

2007	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	1										
20A6	1	0.3299									
20A7	1	1	1								
20A8	0.8817	1	0.0292	0.1377							
20A9	1	1	1	1	1						
20A9A	< 0.0001	0.2681	< 0.0001	< 0.0001	1	0.0029					
20B1	1	1	1	1	0.3797	1	< 0.0001				
20B2	1	1	1	1	0.3241	1	< 0.0001	1			
20B3	1	1	1	1	1	1	0.0095	1	1		
20B4	< 0.0001	0.1845	< 0.0001	< 0.0001	1	0.0017	1	< 0.0001	< 0.0001	0.0058	
20B5	1	1	0.0455	0.2011	1	1	1	0.5423	0.4655	1	1

2008	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	< 0.0001										
20A6	1	< 0.0001									
20A7	1	< 0.0001	1								
20A8	< 0.0001	1	< 0.0001	< 0.0001							
20A9	0.0001	0.1327	0.0013	0.0003	1						
20A9A	< 0.0001	1	< 0.0001	< 0.0001	1	1					
20B1	1	< 0.0001	1	1	< 0.0001	0.006	< 0.0001				
20B2	1	< 0.0001	1	1	< 0.0001	0.0159	< 0.0001	1			
20B3	1	< 0.0001	1	1	< 0.0001	0.0228	< 0.0001	1	1		
20B4	< 0.0001	1	< 0.0001	< 0.0001	1	1	1	< 0.0001	< 0.0001	< 0.0001	
20B5	< 0.0001	1	< 0.0001	< 0.0001	1	1	1	< 0.0001	< 0.0001	0.0001	1

Appendix 9. (continued)

2009	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	< 0.0001										
20A6		1 < 0.0001									
20A7		1 < 0.0001	1								
20A8	< 0.0001		1 < 0.0001	0.0001							
20A9	< 0.0001		1 < 0.0001	0.0001	1						
20A9A	< 0.0001		1 < 0.0001	< 0.0001	0.0034	0.0036					
20B1		1 < 0.0001	1		1 < 0.0001	< 0.0001	< 0.0001				
20B2		1	0.0006	0.8078	1	0.8625	0.8191	< 0.0001	1		
20B3	0.1477	0.0112	0.0942	0.9598	1		1 < 0.0001	0.3688	1		
20B4	< 0.0001		1 < 0.0001	< 0.0001	1		1 0.0402	< 0.0001	0.1276	1	
20B5	< 0.0001		1 < 0.0001	0.0004	1		1 0.0013	0.0001	1	1	1

2010	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.0001										
20A6		1 0.0102									
20A7		1 0.0002	1								
20A8	< 0.0001		1 < 0.0001	< 0.0001							
20A9	0.0114		1 0.5306	0.0184	1						
20A9A	0.0001		1 0.0098	0.0001	1	1					
20B1		1 0.013	1		1 < 0.0001	0.6352	0.0124				
20B2		1 < 0.0001	1		1 < 0.0001		0.001 < 0.0001	1			
20B3		1 0.2971	1		1 0.0006		1 0.2883	1	1		
20B4	< 0.0001	0.1598	< 0.0001	< 0.0001	1	0.0024	0.1655	< 0.0001	< 0.0001	< 0.0001	
20B5	< 0.0001		1 0.0001	< 0.0001	1		1 1	1	0.0001	< 0.0001	0.0060

Appendix 9. (continued)

2011	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	< 0.0001										
20A6	1	< 0.0001									
20A7	1	< 0.0001	0.1045								
20A8	0.0001	0.333	< 0.0001	1							
20A9	1	< 0.0001	0.7194	1	0.4663						
20A9A	< 0.0001	1	< 0.0001	< 0.0001	0.1086	< 0.0001					
20B1	1	< 0.0001	0.1091	1	1	1	< 0.0001				
20B2	0.0001	0.2333	< 0.0001	1	1	0.6628	0.0718	1			
20B3	0.0916	0.0004	0.0034	1	1	1	0.0001	1	1		
20B4	< 0.0001	1	< 0.0001	< 0.0001	0.0184	< 0.0001	1	< 0.0001	0.0116	< 0.0001	
20B5	< 0.0001	1	< 0.0001	< 0.0001	0.3120	< 0.0001	1	< 0.0001	0.2172	0.0004	1

Appendix 10. Results ("p" values) of the analysis of multiple comparisons between years by sub-area for PRE2.

Year	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4	20B5
2007 - 2008	1	1	1	1	1	0.2101	0.0003	1	1	1	0.8043	0.5507
2007 - 2009	1	1	1	0.8025	1	0.0009	1	1	1	0.2937	1	1
2007 - 2010	1	1	1	1	1	1	1	1	0.2039	1	1	0.0001
2007 - 2011	1	1	1	1	1	0.0346	1	0.0001	1	0.0019	1	<0.0001
2008 - 2009	1	1	1	1	1	1	0.0879	1	1	1	0.0281	1
2008 - 2010	1	1	1	1	1	1	<0.0001	1	0.142	1	1	1
2008 - 2011	1	1	0.2766	1	1	1	1	0.4315	1	1	0.0475	1
2009 - 2010	1	1	1	0.1063	1	1	0.8425	1	0.0009	1	1	0.0011
2009 - 2011	1	1	1	1	1	1	1	0.0010	1	1	1	0.0002
2010 - 2011	1	1	0.7711	0.8168	1	1	0.0088	0.0307	0.3119	0.5632	1	1

Appendix 11. Results ("p" values) of the analysis of multiple comparisons between sub-areas by year for PRE2.

2007	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	1										
20A6	1	1									
20A7	1	1	1								
20A8	0.0416	1	0.0776	1							
20A9	1	1	1	1	1						
20A9A	1	1	1	1	1	1					
20B1	1	1	1	1	1	1	1				
20B2	1	1	1	1	0.5563	1	1	1			
20B3	1	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	0.3715	1	1	1	1	1	
20B5	1	1	1	1	0.9212	1	1	1	1	1	1

2008	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.369										
20A6	1	1									
20A7	1	1	1								
20A8	0.6157	1	1	1							
20A9	0.0139	1	1	1	1						
20A9A	1	1	1	1	1	1					
20B1	0.004	1	1	0.7906	1	1	1				
20B2	0.6616	1	1	1	1	1	1	1			
20B3	0.2959	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	1	0.1273	1	0.0483	1	1	
20B5	1	1	1	1	1	1	1	0.8556	1	1	1

Appendix 11. (continued)

2009	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	< 0.0001										
20A6	1	0.0012									
20A7	0.0007	1	0.1023								
20A8	0.0004	1	0.0715	1							
20A9	< 0.0001	1	< 0.0001	0.3403	0.4693						
20A9A	< 0.0001	1	< 0.0001	1	1	1					
20B1	0.0008	1	0.1187	1	1	0.2964	1				
20B2	0.0001	1	0.0258	1	1	1	1	1			
20B3	0.0768	1	1	1	1	0.0045	0.4837	1	1		
20B4	1	1	1	1	1	0.0001	0.0237	1	1	1	
20B5	1	0.0030	1	0.2134	0.1497	< 0.0001	< 0.0001	0.2465	0.0567	1	1

2010	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.2494										
20A6	1	1									
20A7	0.0003	1	0.0320								
20A8	0.0218	1	0.9877	1							
20A9	1	1	1	0.8832	1						
20A9A	1	0.1139	1	0.0001	0.0085	1					
20B1	1	1	1	1	1	1	1				
20B2	< 0.0001	0.4288	< 0.0001	1	1	0.0032	< 0.0001	0.0044			
20B3	1	1	1	1	1	1	1	1	0.0059		
20B4	1	1	1	0.0664	1	1	1	1	0.0001	1	
20B5	1	1	1	0.3165	1	1	1	1	0.0009	1	1

Appendix 11. (continued)

2011	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.0153										
20A6	1	0.0472									
20A7	1	1	1								
20A8	0.0343	1	0.0995	1							
20A9	0.0247	1	0.0734	1	1						
20A9A	1	1	1	1	1	1					
20B1	0.7071	1	1	1	1	1	1				
20B2	0.0186	1	0.0563	1	1	1	1	1			
20B3	1	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	1	1	1	1	1	1	
20B5	0.8380	1	1	1	1	1	1	1	1	1	1

Appendix 12. Results ("p" values) of the analysis of multiple comparisons between years by sub-area for BF.

Year	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4	20B5
2007 - 2008	1	1	<0.0001	1	1	1	1	0.0570	0.5925	1	1	1
2007 - 2009	1	1	<0.0001	1	1	0.1053	1	1	0.0170	1	1	1
2007 - 2010	0.0003	1	<0.0001	0.4434	1	0.0117	1	1	0.0005	1	1	1
2007 - 2011	0.2807	1	0.0052	1	1	0.1053	1	0.0115	1	<0.0001	1	1
2008 - 2009	1	1	1	1	1	1	1	1	1	1	1	1
2008 - 2010	0.0060	1	1	1	1	1	1	1	1	1	1	1
2008 - 2011	1	1	1	0.4227	1	1	0.1402	1	1	0.0031	1	1
2009 - 2010	0.9539	1	1	0.0177	1	1	1	1	1	1	1	1
2009 - 2011	1	0.5620	1	1	1	1	0.0817	1	1	0.0001	1	1
2010 - 2011	1	1	1	0.0004	1	1	0.6281	1	1	0.0007	1	1

Appendix 13. Results ("p" values) of the analysis of multiple comparisons between sub-areas by year for BF.

2007	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	1										
20A6	1	1									
20A7	1	1	1								
20A8	0.0416	1	0.0776	1							
20A9	1	1	1	1	1						
20A9A	1	1	1	1	1	1					
20B1	1	1	1	1	1	1	1				
20B2	1	1	1	1	0.5563	1	1	1			
20B3	1	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	0.3715	1	1	1	1	1	
20B5	1	1	1	1	0.9212	1	1	1	1	1	1

2008	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.3690										
20A6	1	1									
20A7	1	1	1								
20A8	0.6157	1	1	1							
20A9	0.0139	1	1	1	1						
20A9A	1	1	1	1	1	1					
20B1	0.0040	1	1	0.7906	1	1	1				
20B2	0.6616	1	1	1	1	1	1	1			
20B3	0.2959	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	1	0.1273	1	0.0483	1	1	
20B5	1	1	1	1	1	1	1	0.8556	1	1	1

Appendix 13. (continued)

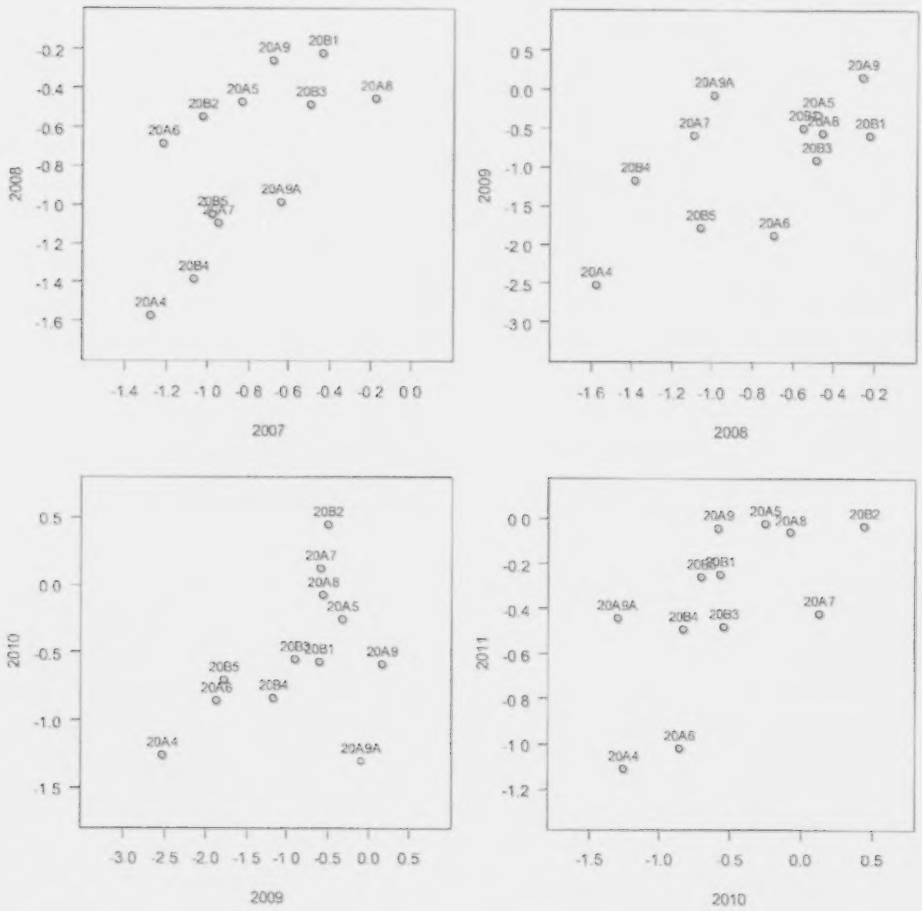
2009	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	< 0.0001										
20A6	1	0.0012									
20A7	0.0007	1	0.1023								
20A8	0.0004	1	0.0715	1							
20A9	< 0.0001	1	< 0.0001	0.3403	0.4693						
20A9A	< 0.0001	1	< 0.0001	1	1	1					
20B1	0.0008	1	0.1187	1	1	0.2964	1				
20B2	0.0001	1	0.0258	1	1	1	1	1			
20B3	0.0768	1	1	1	1	0.0045	0.4837	1	1		
20B4	1	1	1	1	1	0.0001	0.0237	1	1	1	
20B5	1	0.0030	1	0.2134	0.1497	< 0.0001	< 0.0001	0.2465	0.0567	1	1

2010	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.2494										
20A6	1	1									
20A7	0.0003	1	0.0320								
20A8	0.0218	1	0.9877	1							
20A9	1	1	1	0.8832	1						
20A9A	1	0.1139	1	0.0001	0.0085	1					
20B1	1	1	1	1	1	1	1				
20B2	< 0.0001	0.4288	< 0.0001	1	1	0.0032	< 0.0001	0.0044			
20B3	1	1	1	1	1	1	1	1	0.0059		
20B4	1	1	1	0.0664	1	1	1	1	0.0001	1	
20B5	1	1	1	0.3165	1	1	1	1	0.0009	1	1

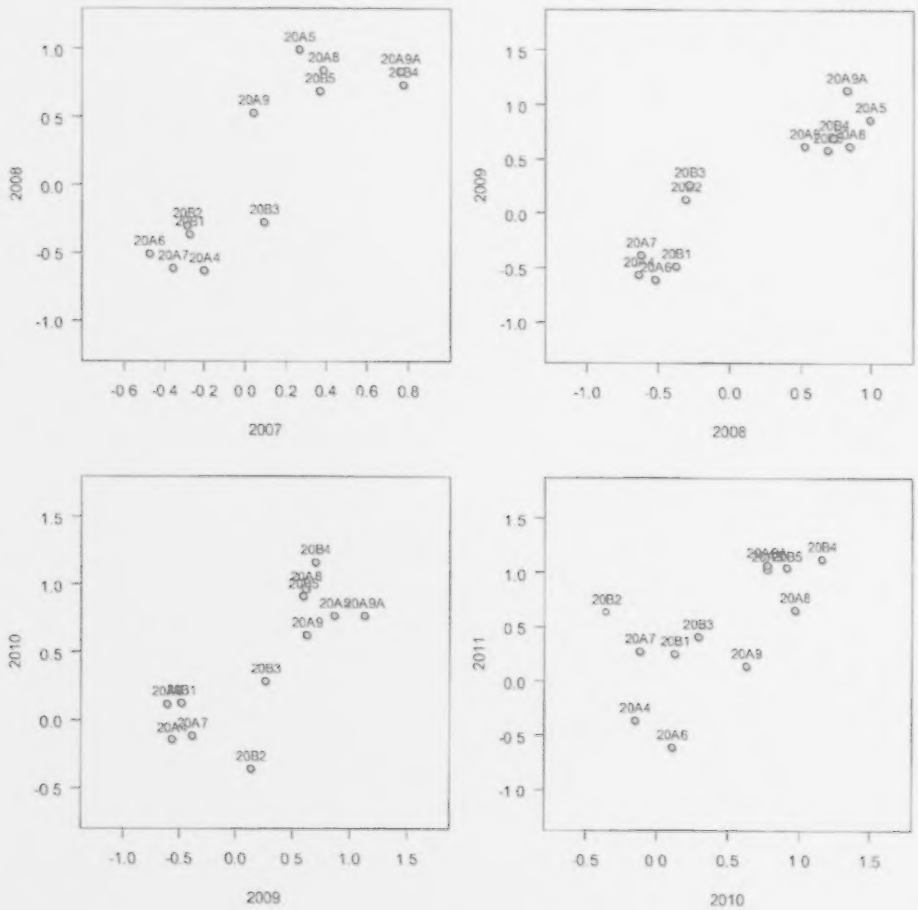
Appendix 13. (continued)

2011	20A4	20A5	20A6	20A7	20A8	20A9	20A9A	20B1	20B2	20B3	20B4
20A5	0.0153										
20A6	1	0.0472									
20A7	1	1	1								
20A8	0.0343	1	0.0995	1							
20A9	0.0247	1	0.0734	1	1						
20A9A	1	1	1	1	1	1					
20B1	0.7071	1	1	1	1	1	1				
20B2	0.0186	1	0.0563	1	1	1	1	1			
20B3	1	1	1	1	1	1	1	1	1		
20B4	1	1	1	1	1	1	1	1	1	1	
20B5	0.8380	1	1	1	1	1	1	1	1	1	1

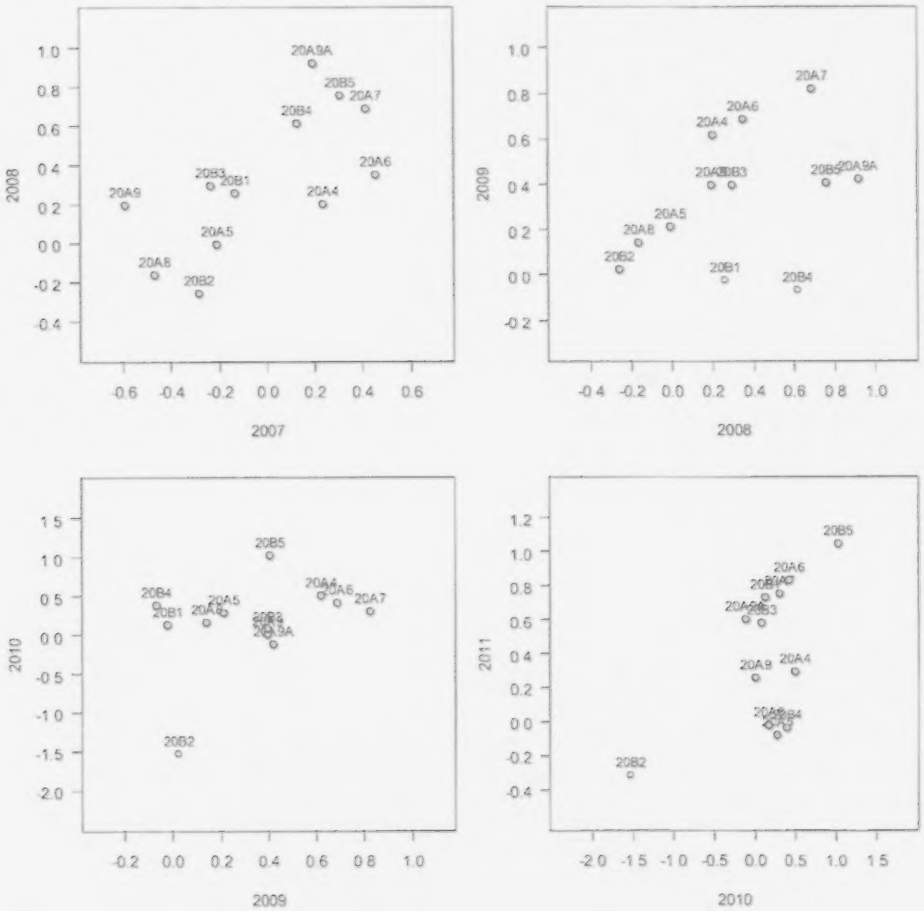
Appendix 14. Relationship between the abundance of COM from various sub-areas for two consecutive years. Abundance corresponds to the mean annual CPUE (natural logarithm), which were used in the correlation analyses. The empty circles represent extreme values that were excluded from the analyses.



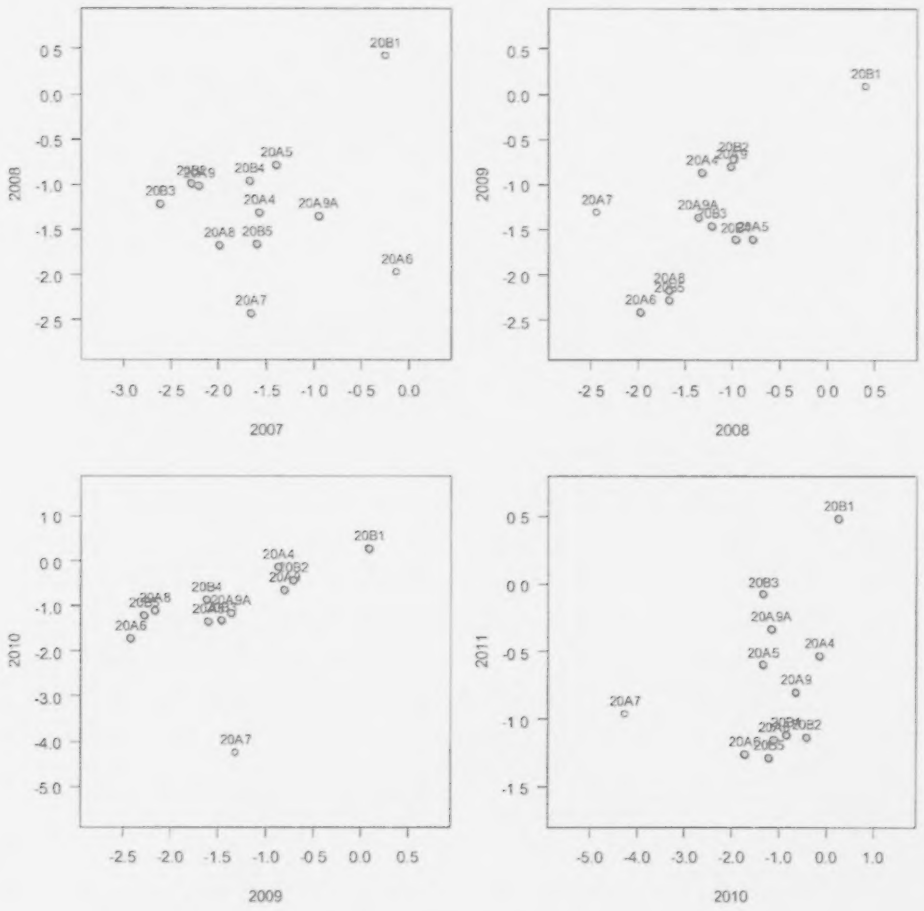
Appendix 15. Relationship between the abundance of PRE1 from various sub-areas for two consecutive years. Abundance corresponds to the mean annual CPUE (natural logarithm), which were used in the correlation analyses. The empty circles represent extreme values that were excluded from the analyses.



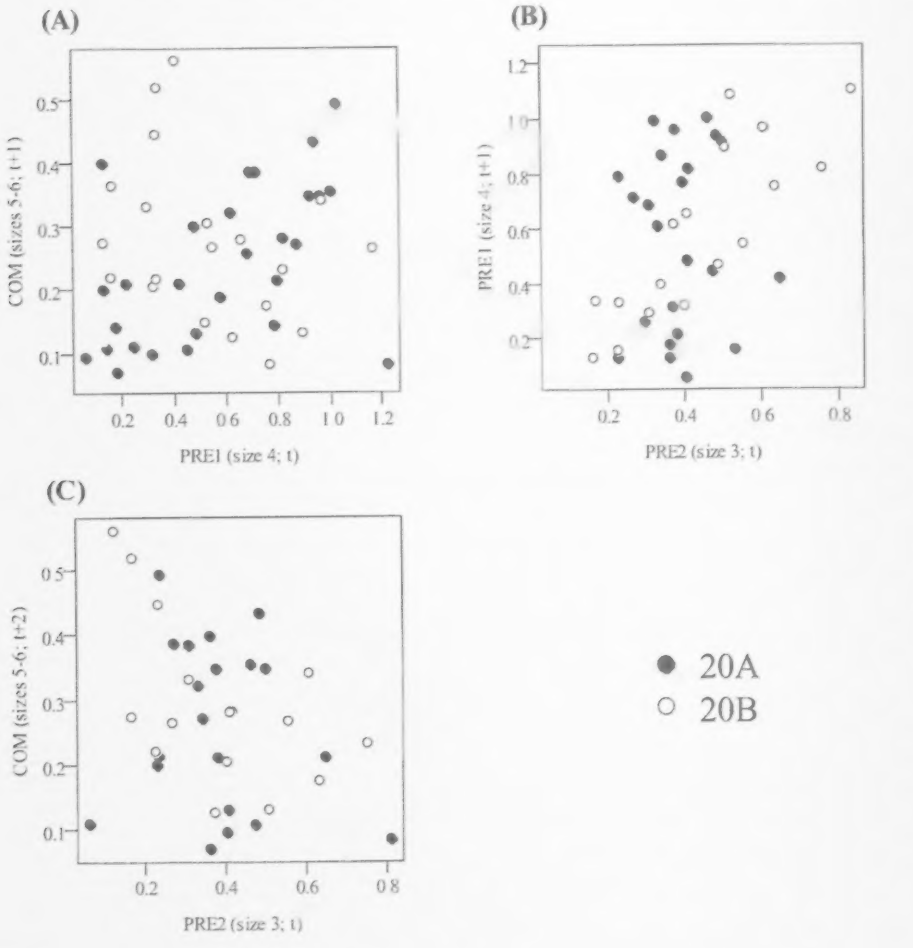
Appendix 16. Relationship between the abundance of PRE2 from various sub-areas for two consecutive years. Abundance corresponds to the mean annual CPUE (natural logarithm), which were used in the correlation analyses. The empty circles represent extreme values that were excluded from the analyses.



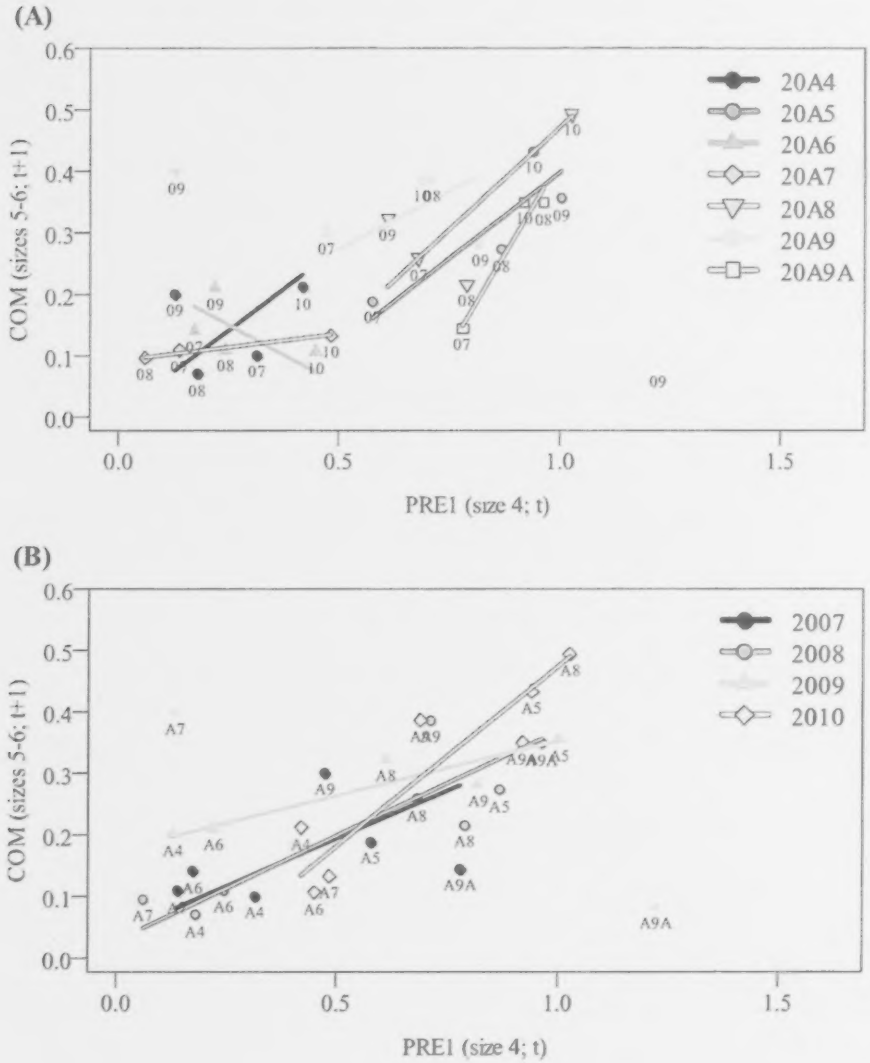
Appendix 17. Relationship between the abundance of BF from various sub-areas for two consecutive years. Abundance corresponds to the mean annual CPUE (natural logarithm), which were used in the correlation analyses. The empty circles represent extreme values that were excluded from the analyses.



Appendix 18. Relationship between the abundance of the different categories of lobster (A: COM-PRE1, B: PRE1-PRE2 and C: COM-PRE2). Each graph includes the five years (2007 to 2011). Abundance corresponds to the mean annual CPUE for each sub-area of Areas 20A and 20B.

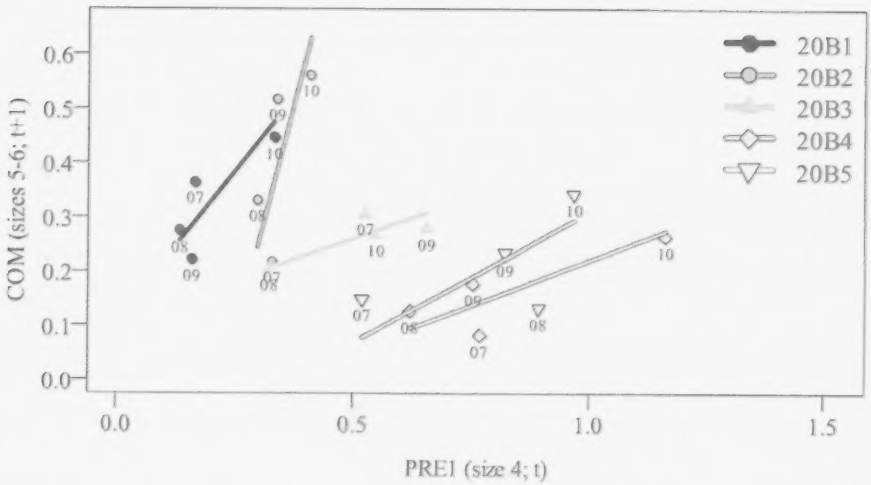


Appendix 19. Relationships between the abundance of PRE1 (size 4) and COM (sizes 5-6) for consecutive years (t = 2007-2010 and t+1 = 2008-2011). The abundance corresponds to the mean annual CPUE for each sub-area. Trends for each sub-area (A and C) and trends for each year (B and D) are presented for each area (20A: A and B, 20B: C and D) and were estimated by the standard major axis. Extreme values are identified by "*" and were not considered in the trends.

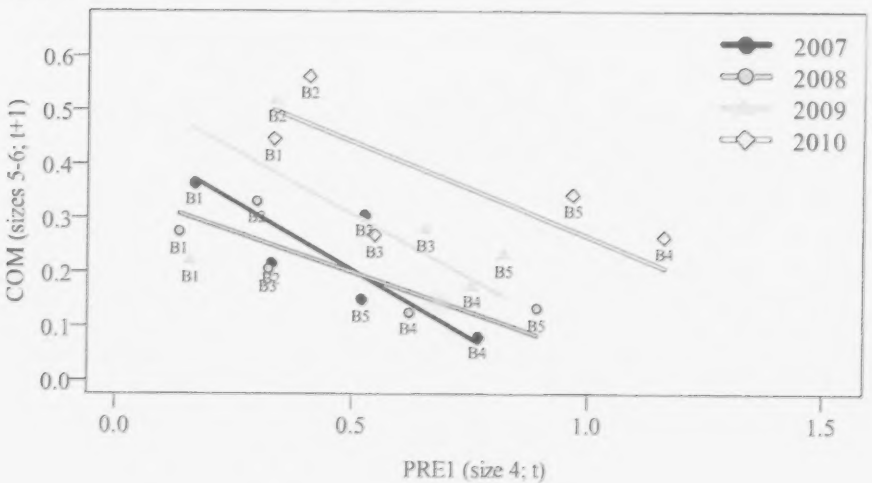


Appendix 19. (continued)

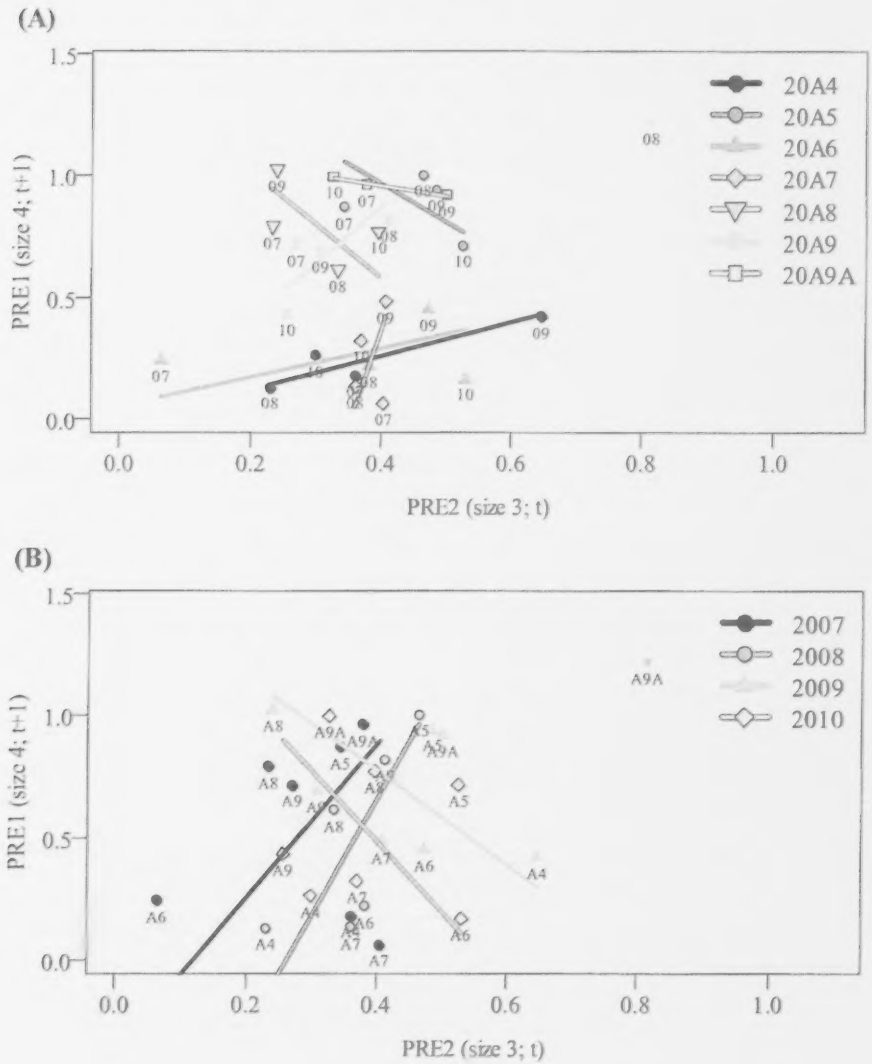
(C)



(D)

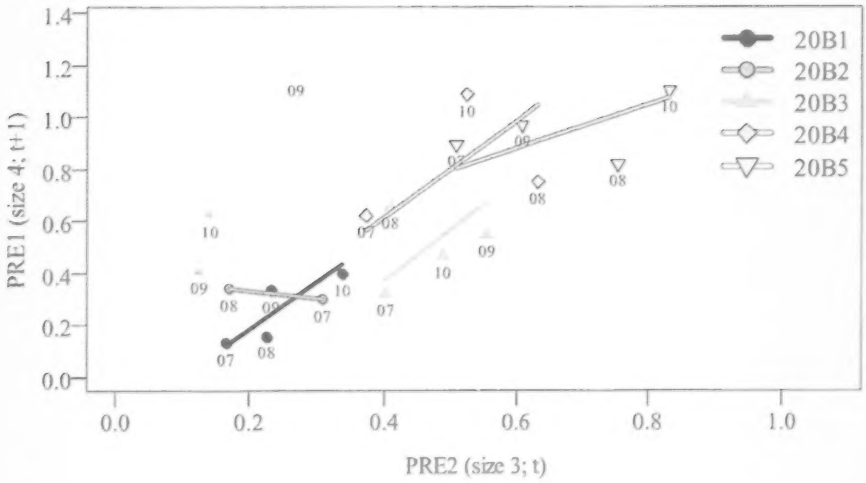


Appendix 20. Relationships between PRE2 (size 3) and PRE (size 4) for consecutive years (t = 2007-2010 and t+1 = 2008-2011). The abundance corresponds to the mean annual CPUE for each sub-area. Trends for each sub-area (A and C) and trends for each year (B and D) are presented for each area (20A: A and B, 20B: C and D) and were estimated by the standard major axis. Extreme values are identified by "*" and were not considered in the trends.

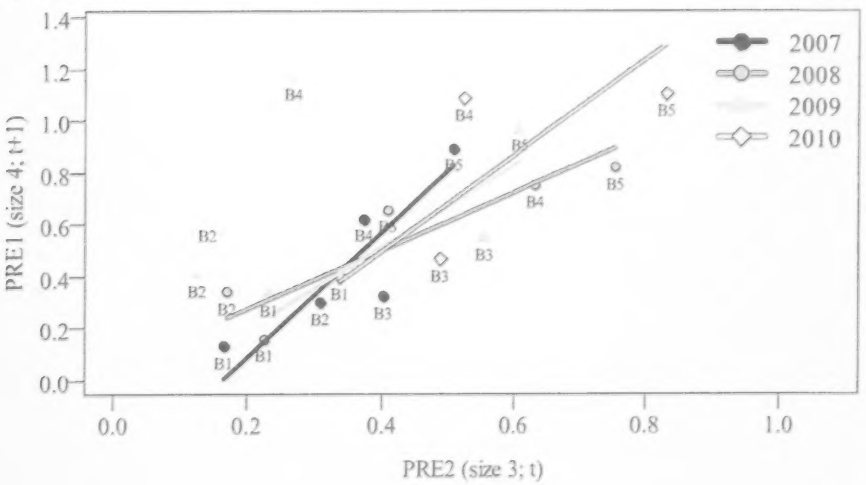


Appendix 20. (continued)

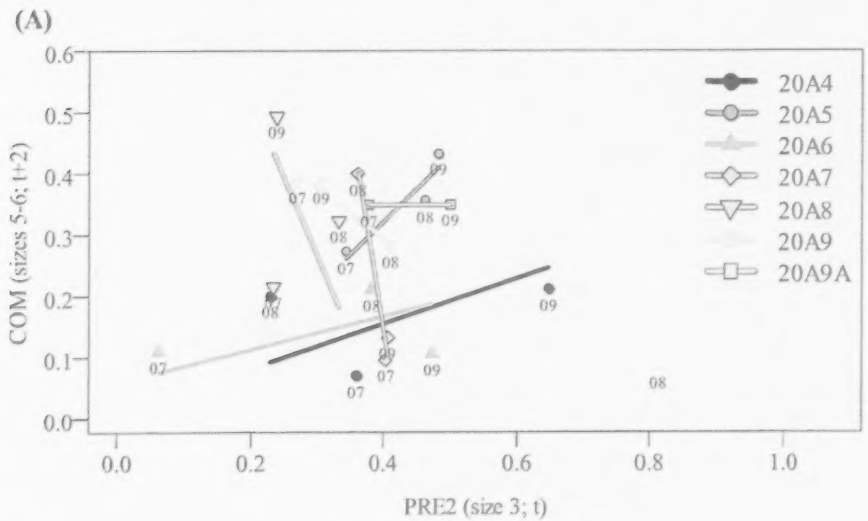
(C)

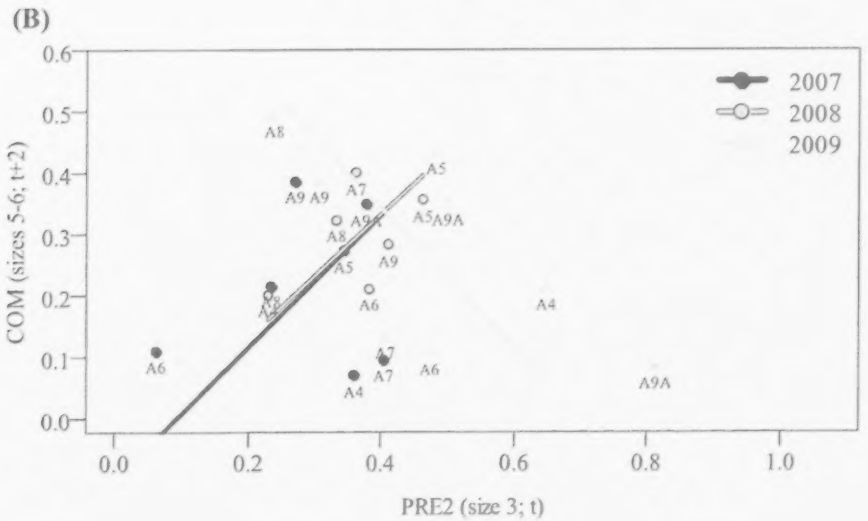


(D)



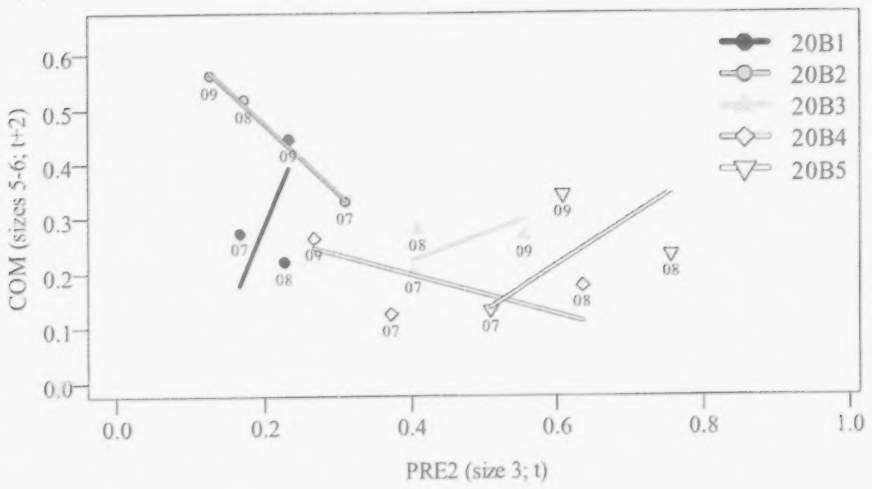
Appendix 21. Relationships between PRE2 (size 3) and COM (sizes 5-6) sparated by a 2-y interval(t = 2007-2009 and t+2 = 2009-2011). The abundance corresponds to the mean annual CPUE for each sub-area. Trends for each sub-area (A and C) and trends for each year (B and D) are presented for each area (20A: A and B, 20B: C and D) and were estimated by the standard major axis. Extreme values are identified by "*" and were not considered in the trends.





Appendix 21. (continued)

(C)



(D)